行政院所屬各機關因公出國人員出國報告書

出國類別：其他

出席「聯合國氣候變化綱要公約第六次締約國大會」報告

出國人：行政院經濟建設委員會

副處長　吳家昌

出國地點：荷蘭海牙

出國期間：89 年 11 月 11 日至 26 日

系統識別號:C08907599

公 務 出 國 報 告 提 要

報告名稱: 參加「聯合國氣候變化綱要公約締約國第六次大會」
主辦機關: 行政院經濟建設委員會
聯絡人／電話: 吳家昌／(02)23165394
出國人員: 吳家昌 行政院經濟建設委員會 都住處 副處長
出國類別: 其他
出國地區: 荷蘭
出國期間: 民國 89 年 11 月 11 日 -民國 89 年 11 月 26 日
報告日期: 民國 90 年 01 月 10 日
分類號/目: G0／綜合（各類工程） G0／綜合（各類工程）
關鍵詞: 聯合國氣候變化綱要公約第六次締約國大會, 溫室氣體
內容摘要:

全球氣候變化所引發的問題相當廣泛，包括土地利用與森林管理、生物多樣性維護、影響人類健康的疾病傳染、糧食安全及貿易自由化多邊環境協議等課題，甚至引起重大的災難，包括海平面上升、陸地沉沒、洪患、旱災、糧食減產、物植滅絕等，所造成之傷害遠甚於戰爭。其所涉及的因應對策包括國土規劃、能源效率提升、再生能源技術的研發、綠色建築、以及政策工具等，均需要透過整體的規劃，以尋求最佳政策與措施。

我國應及早建立抑制溫室氣體的能力，由政府研擬具體行動方案，包括：建立適當的法律體制、智慧財產權保護、加強金融配合、提升對環境友善技術之競爭力及市場的開放等，未來應針對全球氣候變化，考量土地之承載能力，訂定一套適用之發展機制，維護土地資源之永續利用。

頁數: 24 含附件: 否

本文電子檔已上傳至出國報告資訊網

摘　要

全球氣候變化所引發的問題相當廣泛，包括土地利用與森林管理、生物多樣性維護、影響人類健康的疾病傳染、糧食安全及貿易自由化多邊環境協議等課題，甚至引起重大的災難，包括海平面上升、陸地沉沒、洪患、旱災、糧食減產、物植滅絕等，所造成之傷害遠甚於戰爭。其所涉及的因應對策包括國土規劃、能源效率提升、再生能源技術的研發、綠色建築、以及政策工具等，均需要透過整體的規劃，以尋求最佳政策與措施。

我國應及早建立抑制溫室氣體的能力，由政府研擬具體行動方案，包括：建立適當的法律體制、智慧財產權保護、加強金融配合、提升對環境友善技術之競爭力及市場的開放等，未來應針對全球氣候變化，考量土地之承載能力，訂定一套適用之發展機制，維護土地資源之永續利用。

目　　次

壹、前言

一、聯合國氣候變化綱要公約第六次締約國會議（COP6）及第十三次附屬機構會議第二部份（SB 13 part 2）在今（2000）年 11 月 13 日至 11 月 25 日於荷蘭海牙舉行，計有將近 160 國家，超過 76000 人參加。我國代表團係以工研院名義，以非政府組織身分參加，計有行政院環保署、外交部、經濟部能源會、經濟部工業局、國科會、台綜院、工研院及經建會等，總計十九人參加。希望藉此能了解公約國對遵約程序和機制、京都機制之清潔發展機制（Clean Development mechanism）、共同減量活動、開發中國家能力建置（ability building）、土地利用變遷和森林等議題之最新發展動態和各國因應策略，以為我國政府擬定及相關政策之參考。

二、「聯合國氣候變化綱要公約」自一九九二年於巴西簽署後，及至一九九七年第三次大會簽訂「京都議定書」時約有二萬人參加。有鑒於「聯合國氣候變化綱要公約」對於管制二氧化碳排放量、進而衍生違反公約罰則等問題，已成為國際間關注的重點。尤其本次增加「土地利用、土地利用變更及森林」議題，要求締約國計算土地利用變化及推廣造林對於二氧化碳排放量之影響。攸關目前政府研擬與推動綠色矽島有關永續發展方案工作至鉅。會議的進行過程以及相關議題內涵，均值我國密切注意與參採。

三、次締約國會議係針對第 12 及 13 次附屬機構會議（簡稱 SB12 及 SB13）決議事項進行討論及協商，並依第四次締約國會議通過「布宜諾斯艾利斯行動方案」對議定書細節所訂定的工作時程，希望達成決議，促使京都議定書能於 2002 年正式生效。

貳、聯合國氣候變化綱要公約第六次締約國會議議程

一、時間

2000 年 11 月 13 日至 11 月 25 日

二、地點

荷蘭海牙 Netherlands Congress Center （NCC）

三、會議議程

（一）會議開幕

1.第五次大會主席致詞

2.第六次大會主席選舉

3.主席致

4.致歡迎詞

5.執行秘書發言

（二）組織事務

1.公約與京都定書批准情形

2.通過議事規則

3.通過議程

4.接納觀察員組織

5.工作安排，包括附屬機構會議

6.第七次締約國大會之時間與地點

7.公約各機構會議之日程

8.通過全體證書審查報告

（三）附屬機構及其決議與結論報告

1.附屬科技諮詢機構報告（SASTA）

2.附屬履行機構報告（SBI）

（四）審查各項承諾與公約其他條款的執行情形

1.公約附件一國家之國家通訊

2.公約非附件一國家之國家通訊

3.全球環境基金向大會報告

4.能力建置

5.技術發展與移轉

6.公約條款 4.8 與 4.9 的執行情形

7.試驗階段共同減量活動

8.附屬機構第十二次與第十三次會議提交締約國會議相關之其他事項

（ 五 ）第二次審查公約條款 4.2（a）與（b）之適當性

（ 六 ）修改公約附件一與附件二國家名單，移除土耳其之提案

（ 七 ）公約締約國之議定書締約國會議（COP/MOP）第一次締約國會議的準備

1.有關京都議定書 5，7，8 之國家體系、調整與指南

2.「土地利用、土地利用變更及森林」相關事務

3.各種機制之工作方案（決議文 7/CP.4 與 14/CP.5）

4.關於遵守京都議定書之程序與機制

5.政策與措施之最佳做法

6.京都議定書條款 3.14 相關事務

7.單一計畫對承諾期間排放的衝擊（決議文 16/CP.4）

8.附屬機構第十二次與第十三次會議提交締約國會議相關之其他事項

（ 八 ）行政與財務事項

（ 九 ）締約國等代表之發言

（ 十 ）其他事務

（十一）會議結論

1.通過第六次締約國大會報告

2.大會閉幕

參、會議內容摘要

一、第六次締約國會議的開幕式於 11 月 13 上午十時假荷蘭議會中心（Netherlands Congress Centre）正式舉行。由荷蘭環保部長 Jan Pronk 擔任會議主席，荷蘭女皇（Her Majesty Queen Beatrix of the Netherlands）親臨會場參加並致歡迎詞。Jan Pronk 在致詞時表示於京都會議時各附件一締約國已達成溫室氣體減量目標的承諾，第六次締約國會議的與會代表將針對達成減量目標的機制及細節等協商。由於各個國家對各項關鍵議題仍有不同的立場，Jan Pronk 極力主張各國代表能針對所有議題有合理的妥協並作出平衡且可信的決定，俾促使京都議定書能於 2002 年正式生效。

二、IPCC 主席 Robert Watson 於會中報告該機構最近完成的氣候變遷第三次評估結果，指出最近 20 年的大氣溫度達近千年來最高溫，預測 2100 年地球表面溫度將增加 1.5℃至 6℃，幾乎為 IPCC 於 5 年前第二次評估報告預測值的 2 倍，主要原因是大氣中硫及 CO2 排放的增加。大氣溫度的升高，將對水資源、農作物、自然生態系統及人類健康等造成負面衝擊。

三、目前共有 183 個國家簽署聯合國氣候變化綱要公約；其中 84 個國家簽署京都議定書，有 30 個國家已批准，不過，分析指出歐盟批准的可能性相當高。而蘇聯、中國大陸與南美洲等國家是 CDM 機制的最大受惠者，因此對批准議定書是相當肯定的。日本一向對議定書於京都會議通過引以為傲，因此也必然會批准。加上 2002 年為里約地球高峰會議之 10 週年慶，因此在政治面上，當年生效通過的可能性便相當明顯。即使美國不願簽署，但前述的幾個國家的批准，應已超過京都議定書生效的條件（批

准的國家超過 55 個，其排放量佔總量之 55%以上)。

四、附屬機構 SBI 及 SBSTA 分別或共同召開各項議題的協商會議，希望能取得共識達成決議。這些會議原則上是不對外開放的，協商過程中各國代表針對文件初稿字字斟酌，均希望為該國家取得最大利益。附屬履行機構（Subsidiary Body for Implementation, SBI）通過的決議草案包括國家通訊及財務機制；科學技術諮詢機構（Subsidiary Body for Scientific And Technological Advice, SBSTA）通過的決議草案包括土地利用變更及森林（LULUCF）、技術發展移轉、政策及措施及與其他相關國際組織合作;SBI 和 SBSTA 通過的決議草案包括能力建置、遵約體制、共同減量活動、議定書機制及不利影響等。

五、第二週會議於 11 月 20 日上午 10 時開始，荷蘭女皇再次親臨會場，顯示其對此次海牙會議的重視。大會歡迎荷蘭總理 Mr. Win Kok 及法國總統 Mr. Jacques Chirac 發表聲明。荷蘭總理表示對全球環境變遷的重視，並採取一些政策要達到減量 6%的標準，未來會視進展持續調整政策。荷蘭目前在研究國內的排放交易，另外有 50%的減量要藉 CDM 來達成。有關溫室氣體減量的預算會持續成長，將和其他國家共同參與聯合減量計畫或進行排放交易，並將額外提供 2 億盾荷幣給開發中國家。

六、法國總統表示科學證據已證實氣候變遷主因，大家有義務採取強而有力的行動為後代子孫保存地球生態環境。歐洲已動員採取行動協助已開發國家持續發展。1992 年里約地球高峰會議使大家產生希望，8 年後非常令人失望，聯合國氣候變化綱要公約只是通過原則。有關溫室氣體之排放，南方國家缺少能力，北方國家缺少意願。以美國為例，其溫室氣體排放量佔全球的四分之一。平均每一個美國人的溫室氣體為法國人的 3 倍，希

望美國能放棄疑慮及猶豫，儘早批准京都議定書。

七、歐聯將起草共同的政策，各個國家正在制定其國家方案，歐聯對京都議定書的立場是京都機制要靈活、補充全球環境基金的資助要增加、不要關閉協商大門、對 Sink 要謹慎、國際空運排放問題要重視、建議未來合併人均排放量等，在海牙不能解決所有問題，但應繼續努力。

八、國際組織聲明

本次會議有 12 個聯合國組織、13 個非政府機構組織及 1 個觀察團在會議中發表聲明。茲將其聲明摘要分陳如次：

1.世界氣象組織（World Meteorological organization, WMO）主張締約國大會應支持氣候方面的研究開發，以解決一些不確定性，特別是針對最易受傷害的國家，並確保支持 IPCC（Intergovernmental Panel on Climate Change）完成其第三次評估報告。

2.IPCC 表示，疾病擴散、海平面上升、珊瑚礁白化將破壞永續發展目標。

3.世界保護聯盟（World Conservation Union）表示，擔心協商的步調太慢。聯合國環境規畫署（UNEP）則催促已開發國家應儘速依相同但不同責任的原則，開始減少其溫室氣體排放量。

4.The UN Department of Economic and Social Affairs 強調協商過程以追求永續發展為原則，並警告協商代表討論內容不要弄的太複雜及太技術性而偏離對過程的了解。

5.The Organization of Economic Cooperation and Development（OECD）認為對抗氣候變遷需要加強國際合作及具體的國家政策。The World Council of Churches 要求協商代表要關注在符合環保效率、公平及負責任之原則下提案。

6.Milieudefensie 強調要以一般的道德責任拯救公約及議定書。生物多樣化公約秘書處要求締約國確保及維持生物多樣化。

7.UNDP 強調防止氣候變遷對對抗貧窮的重要性，並注意到透過能源部門防止氣候變遷及追求永續發展的機會。世界銀行特別提到環境保護與解決貧窮的關連性。

8.The US Business Council for a Sustainable Energy Future 支持目前的國內排放減量活動及提早行動，建議應儘速推動 CDM，將環保目標轉換成企業的機會。

9.UNIDO 表示，在 CDM 上忽視排放量少的國家而有利於排放量高的國家將會失去公平性，其代表強調能力建置可以克服目前的障礙並有助於推動 CDM 及 JI。

10.國際原子能署（The International Atomic Energy Agency），催促締約國不能基於與防止氣候變遷無關的安全性而將其自 CDM 排除。

11.The International Confederation of Trade Unions 督促政府應與企業及工會組織共同合作以達到防止氣候變遷的長期目標。

12.在利用 sink 減少溫室氣體排放方面，IUCN 表示以生態系統方式處理，應對雙方都有益。The Global Legislators Organization for a Balanced Environment（GLOBE）表示需要增加對 sink 方面的研究以消除其科學上的不確定性，the International Chamber of Commerce（ICC）贊同其論點，但 the Indigenous People's Organization 反對將 sink 納入 CDM。The Confederation of European Forest Owners 表示森林可以提供長期的碳儲存，由森林面積的成長可以計算碳的改變量，而不只是土地利用的改變。

13.The International Gas Union 特別指出使用天然氣可以提供減少溫室氣體排放的機會。The International Institute of Refrigeration 主張通過議定書的好處可以推動技術移轉，並訓練開發中國家的技師減少冷媒部門的溫室氣體排放。

肆、各國對各項議題之基本立場

一、清潔發展機制（CDM）

京都機制一直是已開發國家非常關切的議題，也是最近幾次締約國會議討論的重點，尤其是清潔發展機制（CDM），它是唯一允許附件一國家與非附件一國家協力開發減量計畫之機制。針對 CDM 目前尚在爭議的課題包括：

1.可以納入 CDM 之計畫

CDM 機制的主要目的有二，協助開發中國家永續發展及協助附件一國家減少溫室氣體排放，因此必須符合上述目的之計畫才有可能納入 CDM 計畫。在各國協商過程中較受爭議的是核能計畫及與植林相關之 sink 計畫是否可納入 CDM。

美國對核能計畫並不持反對意見，認為可以公開討論，日本及加拿大希望將核能納入 CDM 計畫。美國、加拿大、澳大利亞、日本及挪威希望將 carbon sink 納入 CDM。最近由瑞士、墨西哥及韓國組成的團體 the Environmental Integrity Group 及秘魯、智利、哥倫比亞、哥斯大黎加、玻利維亞及烏拉圭等國家亦贊同。

歐聯及一些開發中國家如 Tuvalu、Samoa、中國及牙買加等國反對將 carbon sink 計畫納入 CDM。美國於 11 月 14 日協商過程中同意不將 carbon sink 計畫納入 CDM，但必須將既有森林的 carbon sink 納入淨排放計量，否則美國將不會簽署京都議定書。估計透過妥善的森林管理美國既有森林的碳吸收量相當於美國承諾減量目標的 50%。

歐聯對美國同意將 sink（匯）計畫排除於 CDM 表示歡迎，但對美國將既有森林的 carbon sink 納入淨排放計量表示不能同意，仍在協商中。

2. CDM 是否設限

歐聯及歐聯及一些開發中國家認為 CDM 只能做為本國

境內減量行動的補充，必須設限，不能超過本國承諾減量目標的 50%。但是，美國、加拿大、澳大利亞、日本、挪威、蘇聯、烏克蘭及一些開發中國家反對 CDM 設限。

3.匯（Sinks）

在此次締約國會議中引起廣泛的討論，新種植及生長的植物稱為匯，因為它們可以自空氣中去除碳進而減少一個國家的溫室氣體淨排放量。在大部份的已開發國家為達到平衡，土地和森林有匯的功能。但是世界上有很多國家因砍伐森林及變更土地利用反而釋放很多 CO_2 至大氣中。

對某些國家而言建造新的森林可能較減少工業部門的溫室氣體為便宜，由於很困難去估算某一種樹木或森林能吸收多少碳，因此須要一個很精確的計算系統去決定基線及量測其碳變化。

二、共同減量（JI）

依京都議定書的定義，JI 和排放交易（ET）有很大的不同，JI 要搭配額外減量及永續的計畫。附件一所列任一締約國可以向任何其它附件一所列締約國轉讓或從獲得由任何經濟部門旨在減少溫室氣體的各種源的人為排放或增強各種匯的人為清除之計畫所產生的排放減少單位。但任何此類計畫須經有關締約國批准，且任何此類計畫須能減少源的排放，或增強匯的清除，這一減少或增強對任何以其它方式發生的減少或增強是額外的。

另外值得注意的是，共同減量的特色是以某一特定計畫為基礎，而排放減少單位的獲得應是對為履行依第 3 條規定的承諾而採取的本國境內減量行動的補充。同樣對於 JI 是否要設上限各個國家亦有不同的意見。

三、排放交易（ET）

所謂排放交易是指為履行其依第 3 條規定的承諾目標，附件所列締約國可以參與排放交易，任何此種交易應是對為實現該條規定的量化的限制和減少排放的承諾之目的而採取的本國境內減量行動的補充。

四、遵約體制

第五次締約國會議時多數國家代表均要求必須制訂強而有效的遵約體制，附屬機構 SB-13 part 1 會議已討論初稿，希望修改的遵約體制能於此次 COP6 會議中通過。

目前已達共識的是設置一遵約委員會，會下設促進事務組（facilitation branch）及執行事務組（enforcement branch）。促進事務組負責向所有締約國提供執行議定書的諮詢意見，執行事務組負責遵守議定書的相關條款。此外京都議定書中有各項必須遵守的條款，因不遵約條款不同而有不同的罰責。

1.若確定不遵守第 5 條及第 7 條，將暫時停止締約國參與京都機制的權利，並定期提交如何履行該不遵約之進度報告。

2.若確定不遵守第 6 條(JI)、第 12 條(CDM)及第 17 條(ET)，將暫時停止締約國參與京都機制的權利。若締約國屬第 4 條（共同履行，指於同屬某區域經濟一體化組織內的締約國共同行事），則該組織內所有締約國將同時停止參與京都機制的權利。

3.若確定不遵守第 3.1 條（指定減量額度），G11 及中國認為應採取最嚴厲的措施，包括繳交遵約基金、下一個減量期程減少更多的量、提交履約的行動計畫等。

4.若確定不遵守第 3.14 條（不利影響），必須提交承諾其履行第 3.14 條的行動計畫，否則可能會被停權。

五、技術發展與移轉

由於開發中國家一再表示缺乏必要的技術與 "know how" 來對抗氣候變遷，必須透過真正的環境技術轉移，才可以保證開發中國家之永續發展。在協商過程中各國代表們針對評估技術需求（technology needs assessment）、技術資訊（ technology information），能夠的環境（enabling environments）、能力建置（ capacity building）及技術移轉機制（technology transfer mechanism）等五項主題提出其觀點。

在評估技術需求方面，針對是技術開發及轉的技術是否只限定在溫室氣體減量技術或一般對環境友善技術全部涵蓋在內

有不同的意見。另外對於協助移轉發展技術是否在文件中特別指明轉移給經濟轉型國家或是特別指出為開發中國家亦有不同的意見。

在能夠的環境方面，G77和中國表示開發中國家是否執行能夠的環境將視附件一國家執行其減量承諾而定。美國提案鼓勵開發中國家透過CDM推廣高效率環境友善技術市場，中國大陸、巴西及泰國反對將技術移轉和CDM掛勾，應將技術移轉和公約連在一起。

六、在能力建置方面

COP 6會議必須強調加強開發中國家對抗氣候變遷的能力是非常重要的，開開發中國家正在尋求協商同意能力建置及技術移轉特別是來自非附件一國家的財務及技術資助。G77與中國表示這一部份的進展緩慢，未來是否會以包裹方式同意COP 6的協商將視對此議題的滿意程度來定。

能力建置將分兩部份討論，經濟轉型期國家的能力建置及開發中國家的能力建置，主要目的是建立這些締約國的能力，使它們能夠有效地實現公約的目標。

1.經濟轉型期國家的能力建置

經濟轉型期的締約國有被京都議定書限制和減少排放的量化指標，這些國家正處於經濟轉型的過渡期，需要增強能力來對付氣候變遷問題。因此能力建置對這些國家有效履行京都議定書的承諾至為重要。

2.開發中國家（非附件一國家）的能力建置

為幫助開發中國家通過實現京都議定書的永續發展目標，開發中國家的能力建置對於使其能充份參與和有效執行依公約所作的承諾非常重要。體制上的能力建設範圍，包括增強和或創造提高能力的環境、國家通訊、溫室氣體清冊、排放數據管庫管理、技術開發與移轉等等。

七、各國代表聲明

1.奈及利亞代表G77表示，COP6的討論應依據公平及公正原則。注意到有許多附件一國家並沒有履行他們溫室氣體排放

減量或提供技術移轉及財務支援等承諾。他們反對由關鍵附件一國家（Key Annex 1 Country）的提案試圖將財務支援開發中國家的條款限定對一些新增排放減量承諾的國家，強調應透過財務機制的條款來協助開發中國家。

2.Samoa 代表島國聯盟表示，不論在 1992 年已採納預防性的原則，附件一國家的行動還在強調氣候變遷的重要性。

3.法國代表歐聯強調已開發國家的國內減量活動對履行該國承諾具有重要意義。瑞士代表表示，CDM 應依據增量（incremental） 原則處理。

4.一群中歐及東歐締約國組成一個稱為中央集團 11（Central Group 11，簡稱 CG 11）的新團體，此團體在京都議定書訂有減量承諾，他們的共同願望是希望能加入歐聯組織。CG 11 的成員包括保加利亞、Croatia，捷克、Estonia、匈牙利、Latvia、波蘭、羅馬尼亞、Slovakia、Slovenia 和 Lithuania 等 11 個國家，在 COP6 會議期間由 Slovakia 負責連繫協調。

伍、週邊活動（Side Events）

一、日本經團連自主行動方案第三次審查結果報告

1. 日本經濟組織連合會(Japanese Federation of Economic Organizations，日文名稱為 Keidanren，簡稱經團連)認知到氣候變遷議題所呈現的新挑戰，於 1997 年第三次締約國會議時提出自主行動方案，至今已推動三年，經團連自主行動計畫的減量目標是至 2010 年日本產業部門及能源轉換部門的 CO_2 排放量要降至 1990 年水準以下，產業部門及能源轉換部門正朝此減量目標努力。此次追縱結果，1999 年 CO_2 實際排放量為 4.7865 億噸，較 1998 年增加 2.9%，較 1990 年減少 0.1%。而預估 2005 年排放量 4.9951 億噸 CO_2 (比 1990 年增加 4.3%)。依據基本情境(business as usual, BAU)下 2010 年排放量是 5.2404 億噸 CO_2（比 1990 年增加 9.4%)。

二、世界銀行碳基金

世界銀行於 2000 年 1 月 18 日起籌措碳基金擬投資於開發中國家碳減量計畫，目標是 150,000 仟元美金，募集對象為附件一國家及企業集團，預定於 2012 年終止。據世界銀行；碳基金擬投資的計畫將利用不同的技術及投資於不同的國家。

三、全球製鋁業自願減量計畫

International Aluminum Institute（IAI）報告全球製鋁業推動的 PFC 自願減量計畫，製鋁業是最早開始推動溫室氣體排放減量的工業之一。IAI 在調查其 25 家會員廠商的 PFC 排放量時發現，這些鋁生產量佔全球 60%的 25 家會員廠商其 1997 年單位 CF_4 排放量(每生產 1 噸鋁排放 CF_4 克數)平均較 1990 年降低 47%，其中以冰島、英國、澳大利亞的績效較佳。目前有 9 個國家的業者參加願減量活動，希望未來蘇聯和中國大陸的廠商也能參加。全球製鋁業將持續推動溫室氣體排放減量計畫，並注意國際間 ET、JI 及 CDM 計畫的進展。

全世界每年生產3千萬噸鋁，其中有30%的原料來自回收廢料。以1997年為例，約5百萬噸鋁廢料用於交通部門，汽車中鋁用料逐年增加，預期於2005年由目前的每輛車113克增加至227克。由於汽車中鋁用料的增加可以減少汽車的重量，相對減少汽車在行駛時二氧化碳的排放量，當然大量使用廢料亦可降低溫室氣體的排放。

四、核能技術與氣候變遷

由國際核能論壇（International Nuclear Forum）的Ms. Maureen Koetz報告核能技術與氣候變遷的關聯性。報告中指出世界上有31個國家有使用核能發電，核能可確保能源的穩定性及可靠性，這些核電廠一共避免全球5億噸碳的排放，其中美國避免的量為1.685億噸碳，歐洲避免2.08億噸碳；核電廠同時也避免其他空氣污染物如二氧化硫的排放。

雖然大部份國家反對將核能納入CDM計畫，但Ms. Maureen Koetz表示應該把核能納入，她認為持續使用零排放的核能才能符合今日人類的需求，而不用擔心下一世代能源供應不足，而且已開發國家必須把核能技術移轉開源中國家才能協助其永續發展。雖然目前大家看好再生能源，但再生能源不可能取代大型發電廠，它只能取代區域性的電力供應。美國、日本等很多國家將繼續運轉既有的核能電廠，她建議決策者在選擇能源時，將核能視為是一種可能的選擇，不要完全排斥。

核能計畫是否可以納入CDM在這次締約國大會上又被提出來討論，美國和加拿大持贊成立場，但遭環保人士嚴厲指責，看來想將核能納入CDM仍有爭議。

五、再生能源及能源效率

美國環保部報告美國目前太陽能、風能、地熱能、生質能、汽電共生的發展現況。在太陽庇能方面有Million Solar Roofs Initiative計畫，至2000年10月安裝了10萬個系統,成本自1980年的$1.00/kWh降至2000年的0.20cent/kWh，預期至2005年為0.10cents/kWh。在風能方面有Wind Power America計畫，預期自2001年12月的4,600MW成長至2020年的80,000MW，

佔全美能源供應的 5%。成本自 1979 年的 40cent/kWh 降至 2000 年的$4-6cent/kWh，目標 2007 年為 2-4cents/kWh。

在能源效率方面，針對電冰箱、空內空調機、中央空調機、洗衣機、熱水器等家電用品訂定能耗標準，預期至 2020 年上述使用家電用品所節省的能源，足夠點亮全美所有住家燈具兩年。在提升節自省能源方面，美國能源部亦提出多項計畫，相關工業也分別提出各項自願減量計畫。雖然美國國內已做了不少溫室氣體排放減量計畫，但是，令人不解的是，為什麼美國堅持 CDM 不設上限，而且遲遲不願批准京都議定書。

六、2000 年氣候技術展示會（Climate Tech 2000 Pavilion）

配合聯合國氣候變化綱要公約第六次締約國會議的舉辦，世界企業永續發展協會（World Business Council for Sustainable Development）、歐洲企業未來能源永續協會（European Business Council for a Sustainable Energy Future）及荷蘭住宅、空間規畫及環保部（Ministry of Housing, Spatial Planning and Environment）等於 11 月 16 日至 22 日假會場附近(Schamhart & Heiligers Building, Catsheuvel 30）共同舉辦 2000 年氣候技術展示會。展示會主要以技術展示為主，包括新能源技術、再生能源技術、提升能源效率技術等。參展的單位除主辦單位外有二十幾個攤位，主辦單位為吸引參訪人員分別於不同日期安排不同主題，包括交通（Transport）、再生能源（Renewable Energy）、能源效率（Energy Efficiency）、排放交易（Emission Trading）等，以下為參訪摘要：

1.Shell International

Shell 為一全球性的跨國公司，其溫室氣體排放的減量目標為 2002 年時較 1990 年水平減少 10%。自 2000 年開始試辦至少 3 年的公司內部排放交易 The Shell Tradeable Emission Permit System（STEPS）將協助其達成溫室氣體排放減量承諾。Shell 展示的內容有家用太陽能設備原型，可設置海岸的風能設施等，這些目前仍屬試驗階段尚未商業化。

2.Kilombero Forests Ltd.（KFL）

這是 Tanzania 國的一家私人公司，參展目的是希望尋找願意至該國投資 CDM 計畫，尤其是有關造林計畫的附件一國家。自 1996 年起 KFL 就開始推動該國 CDM 造林計畫，是由挪威 TreeFarms A/S 在 Tanzania 子公司 Escarpment Forestry Company Ltd.負責開發，該計畫總計投資 1.1 百萬元，取得 12,121 公頃土地的 99 年租期，造林面積 1,700 公頃。

3.Statoil

挪威石油公司 Statoil 主要是推廣其碳固定化技術，將 CO_2 永遠儲存在地質層中。Statoil 表示其可將天然氣中的 CO_2 分離出來（含量約>2%），再將此 CO_2 注入深海中，用於加強石油的回收，且有一部份可存於地底。深海的地質有很多不同形式，如深煤床可以吸收 CO_2，也許可以一併吸收甲烷。

4.RITE 與 ICETT

日本的 RITE（Research Institute of Innovative Technology for the Earth）及 ICETT（International Center for Environmental Technology Transfer），前者主要研發包括碳固定化等的創新技術，後者則推廣技術移轉。日本研究機構及業者在這次締約國大會上相當活躍廣發文宣品，顯示他們對京都議定書的重視。

陸、觀察心得與建議事項

一、觀察心得：

（一）依據大會公布之資料，截至目前為止，氣候變化公約締約國共有一八三國，惟僅有三十國批准京都議定書，離須要五十五個締約國批准始能生效之門檻尚遠，本屆大會主席及大部分締約國代表於大會中均呼籲尚未批准國家應儘速批准，以期議定書於二〇〇二年底前生效。

（二）本屆大會與會代表成立議定書遵約委員會（compliance commission），並在其下設置促進事務組（facilitative Branch）暨執行事務組（enforcement branch）已達成共識，惟對附件一國家及未遵守議定書規定時之處理方式，應負之責任，則意見紛歧。

（三）生物多樣化公約秘書處在會中曾表達與 UNFCCC 合作之意願，其重點議題有二：（1）氣候變化對生物多樣性之影響；（2）執行氣候變化綱要公約及京都議定書時，UNFCCC 在生物多樣性保育方面考慮採取之對策。顯示氣候變化對生物多樣性之維護已產生潛在威脅。

（四）紐約之 The Earth Times 在大會期間每日於會場散發本次大會相關新聞報導，曾刊登台北市街頭交通情況照片，照片下註明"Attention is expected to be turned to developing countries and controls on their emission"。顯然國際間已注意我國溫室氣體排放問題，實值我國注意。

（五）幾個著名的國際組織公司，如 Shell，BP，及 Dupont 等，指派高級主管參與 COP6 會議，並於會議中承諾配合氣候環境改變問題，嚴格管制溫室氣體排放，預

料將建立示範作用，帶動各國積極改善氣候環境。

（六）彈性機制是本屆大會的重要議題，其中，又以 CDM 最受到重視。有關以植樹吸匯 CO_2 是否納入 CDM 中，迄未獲結論，但是「核能」不能作為 CDM 計畫項目，已有漸趨明朗的共識。

（七）聯合國首席科學家沃森在聯合國會議中發言·指出溫室氣體排放之影響，認為延遲不對抗全球暖化問題會使後代面臨更艱鉅的苦戰，長期而言，甚至會造成混亂且破壞力強的氣候變化，下列的一些觀象只是冰山一角：

1.由於全球暖化，海洋溫度上升，許多珊瑚大量死亡。

2.阿拉斯加白令冰河維特斯湖地區在過去一世紀期間，面積減少一百卅平方公里。

3.中共國家測繪局的研究人員發現，由於全球暖化，世界第一高峰喜馬拉雅山珠穆朗瑪峰（聖母峰）的高度下降了。

（八）一九九七年十二月其中：京都議定書訂定未來數年間逐漸減少溫室效應氣體排放量目標，如今三年即將過去，相關目標的落實卻因美國與歐洲聯盟的寬嚴標準分歧而難有進展。森林與農地藉光合作用吸收溫室效應氣體，扮演二氧化碳「匯」的問題，是此次海牙談判中最複雜、爭執最激烈的課題之一。

1.以美國為首的提案，主張由世界銀行及聯合國環境計畫署成立的全球環境基金內另立機構，資助開發中國家減少溫室效應氣體排放的計畫，並幫助這些國家「適應氣候改變帶來的不利後果」。

2.受到多數窮國支持的歐盟表示，每一個已開發國家必須在國內大幅減少溫室氣體的排放，而不能全抑賴以付費方式要求其他國家為他們削減氣體排放，把森林吸收的二氧化碳也算在京都議定書規定的削減配額內。

3.歐盟說，森林與農地為二氧化碳「匯」之說，科學上的證據並不明確，因此，暫時以不認定二者具有吸收溫室效應氣體之利為宜。美國則表示，森林在對抗溫室效應氣體上明顯有益。

4.開發中國家組成的 G77 集團，以及俄羅斯與東歐國家在會議中都表示反對美國的主張。

5.「地球之友」組織表示，如果美國獲許利用所謂的碳匯來達成京都議定書規定的削減氣體排放配額，美國削減碳的成本為每噸一美元，若不准這樣做，成本為每噸三十一美元。

二、建議事項

（一）長久以來，人類對於土地的使用，在追求經濟利益與成長目標之引導下，超高密度之發展，已嚴重破壞土地資源的承受力，尤其開發利益分配不均，違背社會公平正義之原則，此次 COP6 之議，許多與會代表紛紛建議，要求土地之使用應維持下列原則，可供我國參考：

1.依據各類土地資源之承載力，規範土地使用之性質與強度；

2.加強保護農地，避免農地任意變更作非農業使用；

3.土地使用應作多元化之規劃，使自然生態更為豐富；

4.森林面積十分廣闊，牽涉問題複雜，應加強管理，避免濫墾濫伐；

5.應建立土地開發利用之評估指標與審議機制；

6.社區發展應充分考量人民之生活與需求，鼓勵民眾參與；

7.土地利用應從小處著手，建立示範計畫，逐步推廣，永續發展。

8.工業與經濟高度發展，溫室氣體排放過量是造成氣候變化的直接原因，但是，根本解決之道，應從土

地規劃利用或自然環境保育（如限制開發、造林、與綠化）著手。

9.土地利用應充分考量土地之特性與承載能力，並注重區域間之均衡發展與利益之公平分配。

10.開發中國家與環保團體在會議期間之抗爭、暴露了過去經濟發展過程中，土地開發利益與責任分配不公的問題，應儘速建立土地開發利用與環境影響評估的審議機制，俾有效管制開發行為。

（二）全球氣候變化所引發的問題相當廣泛，包括土地利用與森林管理、生物多樣性維護、影響人類健康的疾病傳染、糧食安全及貿易自由化多邊環境協議等課題，甚至引起重大的災難，包括海平面升、陸地沉沒、洪患、旱災、糧食減產、物植滅絕等，所造成之傷害遠甚於戰爭。其所涉及的因應對策包括國土規劃、能源效率提升、再生能源技術的研發、綠色建築、以及政策工具等，均需要透過整體的規劃，以尋求最佳政策與措施。

（三）氣候變化所牽涉之問題十分廣泛複雜，需要各部門的專業知識與技術。因此，各國在研擬解決方案或對策時，必須徵詢專家，溝通民意，以尋求正確有效的方法，俾能確實執行。

（四）自由化與全球化之後，全世界已成為一個生命共同體，各國應摒除自我立場與既得利益，唯有同心協心，才能解決氣候環境變化之問題。

（五）自 1992 年里約氣候變化公約迄今已歷經八年時間，氣候變化問題仍止於談論階段，當務之急，必須達成共識，立刻執行，只有行動，才能解決問題（work it out)。會議達成的共識與結論，必須轉化成各國之政策與法令規章，以為執行之依據。

（六）我國在因應氣候變化綱要公約上，應持續掌握公約和京都議定書之發展趨勢，選擇對我國經濟發展和環境

保護兼籌並顧的立場，以爭取各國之認同。我國亦應盡地球村之責任，在土地與能源政策上，提高使用效率，加強工業、商業、住宅、運輸等各部門節約能源，並鼓勵推廣再生能源發展與應用等措施，加強造林、防止濫墾濫伐。

（七）我國應及早建立抑制溫室氣體的能力，由政府研擬具體行動方案，包括：建立適當的法律體制、智慧財產權保護、加強金融配合、提升對環境友善技術之競爭力及市場的開放等，增加民間對 CDM（Clean Development Mechanism）投資的誘因及參與。同時，可考量成立能力建置、技術評估分析與策略及研究發展案工作小組，推動相關活動，以加速技術之成效。

（八）溫室氣體排放基線資料的估算工作甚為重要，在 CDM 計畫基線資料估計之方法論中，最新發展為多元計畫基線（multi-project baselines）推估法，係以『單位產品』的 CO_2 排放量作為估算基礎，可估算代表整個區域或部門的平均基線排放量。此外，有關 CDM 之成本效益分析及其對永續發展的影響，亦亟待建立研究能力，以作為政策制定之參考依據。

（九）全球化與自由化給人類帶來機會，也帶來威脅，機會與威脅必須協調以獲取均衡。一般而言，北半球多屬已開發的工業化國家，經濟與工業高度發展，釋出過量的 CO_2，改變氣候環境，南半球則多為開發中國家，產業迄未高度發展，仍有許多開發空間。未來應針對全球氣候變化，考量土地之承載能力，訂定一套適用於南、北半球之發展機制，俾全球共同遵守，維護土地資源之永續利用。

Assessment of Potential Effects and Adaptations for Climate Change in Europe

SUMMARY AND CONCLUSIONS

The Europe Acacia Project

(A CONCERTED ACTION TOWARDS A COMPREHENSIVE CLIMATE IMPACTS AND ADAPTATIONS ASSESSMENT FOR THE EUROPEAN UNION)

Report of a Concerted Action of the Environment Programme of the Research Directorate General of the Commission of the European Communities.

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Foreword

This is a summary of the report, Assessment of Potential Effects and Adaptations for Climate Change in Europe, which was funded by the Environment Programme of the Research Directorate General of the Commission of the European Communities. It has been written by 27 scientific experts, many of whom have led major CEC research projects and all of whom are authors of the current assessment by Working Group II of the Intergovernmental Panel on Climate Change. The assumptions and scenarios in the study are similar to those of the IPCC Third Assessment. Indeed, this report has provided the basis from which the chapter on effects of climate change in Europe has been developed for the IPCC Third Assessment, to be published in 2001.

The authors have drawn upon all available published material (the result both of CEC and nationally funded research), and have added their expert judgement and those of their colleagues where literature is absent. The draft chapters were reviewed by 14 additional experts, and revised accordingly. The result is an expert assessment of what we currently know about the effects of climate change and the most effective adaptation to it.

Each chapter in the full report considers: a) key sensitivities to weather now, b) key impacting aspects of climate change in the future, c) most vulnerable sectors and regions, d) main implications for other related sectors, e) implications for other (non-climate trends), f) main uncertainties and unknowns, g) implications for policy, and h) implications for research.

The report is an important synthesis of current knowledge and of its implications for future development and research, and I recommend it to those concerned with these and related tasks.

I am confident that this report will be useful both for the scientific community and policy makers.

A. Ghazi
Head, Biodiversity and Global Change Unit,
European Commission, Brussels.

Preface

A substantial amount of research has now been completed on the possible impacts of climate change on Europe. But this is not coherent because different studies have often adopted different timescales, looked at different regions and assumed different climate change projections of the future.

The Europe ACACIA report draws the disparate knowledge together. This is a summary of that report. The experts were asked to consider all available published and 'grey' literature and, in addition, to make expert judgements regarding impacts and adaptations where information is currently missing but where it could be inferred from other studies.

The primary purpose of the report is to identify key issues for policymakers, planners and researchers. A chapter is allocated to each of the following sectors:

Water Resources	Ecosystems
Soil and land resources	Forestry
Agriculture	Fisheries
Insurance	Transport and energy
Tourism and recreation	Health
Coastal zones	Mountain regions

Each chapter addresses a common set of issues:

- The key sensitivities to weather now.
- The main impacting aspects of climate change in the future.
- The most vulnerable regions.
- The array of adaptive options.
- The key implications for other related sectors and other environmental trends.
- The uncertainties and unknowns.
- Policy implications.
- Research implications.

This 3-year study has provided the basis for the chapter on Europe in the forthcoming Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). In effect the 320 pages of this report have been condensed, and combined with information on Eastern Europe and European Russia, to make the 40 page IPCC assessment for Europe. In this respect there is complete commonality between this ACACIA report and that prepared for the IPCC, though with much more detail in the former.

The climate change scenarios and the socio-economic scenarios adopted here are the same as for the IPCC. Indeed, it was within the Europe ACACIA study that the scenarios were first tested and written up at the regional level.

I am grateful to the 27 expert authors, 12 senior advisers, and 14 reviewers and technical assistants who together developed the Europe ACACIA report.

Professor Martin Parry - Editor
Jackson Environment Institute, School of Environmental Sciences,
University of East Anglia, Norwich, UK

SUMMARY AND CONCLUSIONS

PURPOSE OF THIS ASSESSMENT

This is an assessment of impacts and adaptations to climate in Europe, based upon an expert review of current knowledge. It has drawn upon all available knowledge including the most up-to-date projections of likely future climate change. These scenarios are the same as those adopted in the Third Assessment of the Intergovernmental Panel on Climate Change (IPCC). The authors of this report are those of the IPCC Assessment and the report itself has provided the basis of knowledge from which the IPCC assessment for Europe has been summarised.

Overall, it is evident that:

- The balance of impacts of climate change will be more negative in southern than in northern Europe.
- Primary sectors, such as agriculture and forestry, will be more affected than secondary and tertiary sectors, such as manufacturing and retailing.
- More wealthy regions and sectors will be less adversely affected than more marginal and poorer ones.

Consequently, climate change has major implications for Europe's policies of development and environmental management. The Report makes numerous recommendations regarding these.

OVERALL CONCLUSIONS

Expected changes in Europe's climate

Global climate is warming and ".... the balance of evidence suggests a discernible human influence ....."[1] on this warming. In Europe, mean annual temperature has risen by about 0.8°C during the twentieth century, with the last decade (1990-99) being the warmest on record, both annually and for the winter season. Night-time temperatures have increased more than daytime temperatures, probably related to increasing cloudiness. Precipitation over northern Europe has increased by between 10 and 40 per cent during the twentieth century, whereas some parts of southern Europe have dried by up to 20 per cent.

Four future climate change scenarios are presented for Europe, each scenario assuming a different characterisation of the future world. The climate change patterns associated with each scenario are derived from a set of recently completed global climate model experiments.

- Annual temperatures over Europe warm at a rate of between 0.1°C/decade and 0.4°C/decade. This warming of future annual climate is greatest over southern Europe (Spain, Italy, Greece) and north-east Europe (Finland, western Russia), and least along the Atlantic coastline of the continent. In the winter season, the continental interior of eastern Europe and western Russia warms more rapidly than elsewhere. In summer, the pattern of warming displays a strong south-to-north gradient, with southern Europe warming at twice the rate of northern Europe. Climate model predictions tend to agree most over southern Europe in winter and for north-western and eastern Europe in summer.

- Winters currently classified as cold (occurring 1 year in 10 during 1961-1990) become much rarer by the 2020s and disappear almost entirely by the 2080s. In contrast, hot summers become much more frequent. Under the 2080s scenario, nearly every summer is hotter than the 1-in-10 hot summer as defined under the present climate.

- The general pattern of future change in annual precipitation over Europe is for widespread increases in northern Europe (between +1 and +2 per cent/decade), rather smaller decreases across southern Europe (maximum -1 per cent/decade), and small or ambiguous changes in central Europe. Most of Europe gets wetter in the winter season (between +1 and +4 per cent/decade). In summer, there is a strong gradient of change between northern Europe (wetting of up to +2 per cent/decade) and southern Europe (drying of up to -5 per cent/decade). The inter-model range of seasonal precipitation changes implies that sign differences frequently exist between the precipitation changes simulated by different climate models. The largest inter-model differences tend to occur in southern and northern Europe.

- Global-mean sea-level rises by the 2050s by between 13 and 68cm. These estimates make no allowance for natural vertical land movements. Owing to tectonic adjustments following the last glaciation, there are regional differences across Europe in the natural rates of relative sea-level change. While much of central and southern Europe is slowly sinking (typically by 5cm by the 2080s), much of northern Europe is rising out of the ocean.

The ACACIA scenarios do not explicitly quantify changes in daily weather extremes. However, it is very likely that frequencies and intensities of summer heatwaves will increase throughout Europe, likely that intense precipitation events will increase in frequency, especially in winter, and that summer drought risk will increase in central and southern Europe, and possible that gale frequencies will increase.

A summary of likely effects of climate change in Europe

The basic human topography of the Europe in which climate impacts are likely to be experienced in the future is likely to be very different to the Europe of today. Even the political boundaries of a future Europe and the precise allocation of decision-making tasks across the levels of governance within it could be very different.

The effects of climate change in Europe will involve both losses and gains to the natural resource base. These will vary from region to region, from sector to sector, and within sectors. The significance of these effects will, however, depend to a considerable extent on the non-climate drivers of environmental change, socio-economic development and

[1]Climate Change 1995: The Science of Climate Change. Second Assessment Report of the Intergovernmental Panel on Climate Change. (J. T. Houghton, L. G. Meiro Filho, B. A. Callendar, N. Harris, A. Kattenburg and K. Maskell (eds.) Cambridge University Press, Cambridge.

policy evolution within Europe. In summary, and in very general terms, we may expect that:

- Present-day weather extremes have effects on natur-al, social and economic systems in ways which reveal sensitivities and vulnerabilities to climate change in these systems. In many cases, climate change will aggravate such effects.

- Current and future pressures on water resources and their management in Europe are likely to be exacer- bated by climate change, (partly because the effect of change is uncertain). Flood hazard is likely generally to increase, and the risk of water shortage is projected to increase particularly in southern Europe. Climate change is likely to exaggerate the water resource differences between northern and southern Europe.

- Soil quality will deteoriorate under warmer and drier climate scenarios in most regions of both northern and southern Europe, and this will impair the soil functions that underpin ecosytems and society. The magnitude of this effect will vary markedly between geographic locations and may be moderated by increasing precipitation, except where precipitation changes exacerbate land degradation processes.

- Increasing temperature and CO_2 is expected to result in changing natural ecosystems, increasing the encroachment of trees and shrubs in northern tundra, and broad-leaved trees in parts of northern European coniferous forests, and possibly increasing fire frequency in Mediterranean areas. Net productivity in ecosystems will likely increase (also due to nitrogen deposition and increased carbon dioxide), but carbon storage may not. Diversity of vegetation in some nature reserves is under threat from rapid change. Loss of some critical habitats (wetlands, tundra) would threaten some species (e.g. migratory birds).

- There will be increases of productivity in commercial forests in northern Europe, but likely reductions in the Mediterranean regions and continental Europe, with increased drought and fire risk.

- Increasing atmospheric CO_2 will increase productivity of most crops. This would be counteracted by the risk of water shortage in southern and eastern Europe and by a shortening of the duration of growth in many grain crops due to increasing temperature. Northern Europe is likely to experience overall positive effects, whereas some agricultural production systems in southern Europe may be threatened.

- Climate change is likely to result in faunal shifts affecting freshwater and marine fish and shellfish biodiversity. Changes in fisheries and aquaculture production will be aggravated by unsustainable exploitation levels and environmental change.

- The insurance industry faces potentially costly climate change impacts through the medium of property damage, but there is great scope for adaptive measures if initiatives are taken soon.

- Transport, energy and other industries will face both changing demand and market opportunities, but there will be adverse impacts associated with sea-level rise and changes in the incidence of extreme weather episodes.

- Higher temperatures are likely to cause changes in recreational preferences, stimulating tourism and recreational activities outdoors in northern Europe, but summer heatwaves are likely to modify the traditional peak summer demand at Mediterranean holiday destinations whilst less reliable snow conditions could impact adversely on some winter ski resorts.

- A range of adverse risks are posed for human health through increased exposure to heat and air pollution episodes, extension of some vector-borne diseases (e.g. leishmaniasis, tick-borne encephalitis) and through coastal and riverine flooding.

- In coastal areas the risk of flooding, erosion and wetland loss will increase substantially with implications for human settlement, industry, tourism, agriculture and coastal natural habitats. Southern Europe appears more vulnerable to these changes, although northern Europe already has a high exposure to coastal flooding.

- In mountain regions higher temperatures will lead to an upward shift of biotic and cryosperic zones, and will perturb the hydrological cycle. There will be a redistribution of species with, in some instances, a threat of extinction.

RECOMMENDATIONS

Implications for policy

i) *Present-day weather extremes* (droughts, floods, wind storms etc.) impact upon the natural, social and economic systems of Europe in ways which reveal sensitivities and vulnerabilities to climate change in these systems. Studying the responses to these events can teach us about the appropriateness of (a) coping strategies for extreme weather fluctuations in the short-term, and (b) adaptation strategies to climate change in the longer term.

Sectors vary in their sensitivity to present-day extremes, and in the level of management awareness of the risks posed by present-day extremes and by climate change. Sensitive sectors with low levels of management awareness, such as tourism, are most vulnerable to climate change impacts.

ii) In the *water sector*, the major policy implication of climate change is that it is no longer possible to assume that the future hydrological resource base will be similar to that of the present. This is important in the context of sustainable water management. Water managers, at all levels, therefore need to (a) develop methodological procedures for adopting a scenario-based approach to strategy or scheme assessment, and (b) develop adaptive techniques that allow incremental adjustments over time. A second major implication is that the amount of climate change might make it more difficult to move to more sustainable management of water resources, particularly in the south of Europe.

iii) At present, *soil protection policies* at both the national and international level are very poorly developed, especially in comparison with policies relating to air and water quality. Probably the most developed policy area is for soil erosion and desertification. The UN Convention to Combat Desertification has required Portugal, Spain, France, Italy, Malta and Greece to prepare national action programmes, and some European countries place restrictions on land use to protect against soil erosion, e.g. the active planting of trees and grass to reduce erosion has been encouraged in France, Austria and Iceland. Whilst such policies deal with a problem that occurs now, there is a need for explicit consideration of climate change impacts on degradation processes that will occur in the future.

Thus, given the wide range of land quality issues in the present, and the likely deterioriation in land quality arising from climate change in the future, current policies appear to be inadequate. The implementation of broader policies that aim to preserve the quality of soil and land resources, both in the present and in the future, is needed now. Such policies should be regionalised, targeting specific issues within different European locations.

iv) Many European *ecosystems* are likely to be modified in structure and/or productivity by climate change. Implications for policy – beyond the general need to reduce fossil fuel emissions – have a mainly local and regional character:

- Policies with the goal of conserving the diversity or other services of European ecosystems need to be based on detailed regional assessments, since impacts are regionally different due to climatic and land use gradients, as well as due to the spatially variable signal from climate change.

- Policies can currently not be based on spatially comprehensive assessments of regional threats that may occur in the future. This requires a higher degree of certainty in climate modelling, as well as an improved assessment methodology for the impacts.

- Many European ecosystems are likely to have higher net primary productivity due to higher temperatures, higher CO_2 concentrations and atmospheric nutrient pollution. Environmental policy should, however, not assume that this necessarily implies benefits for many ecosystem services, since disruptions in the present ecological balance are likely to follow (e.g. disturbances, leakage, loss of oligotrophic species). Because soil respiration will increase with higher temperatures, the higher net productivity does not imply increase in carbon storage. It can therefore not be expected that climate change will aid an easier fulfilment of Kyoto commitments.

- Dry ecosystems in the south and the southeast will require an intensified fire protection policy if loss of life and property from more frequent and more intensive fires is to be averted.

- Some ecosystems with particular value for animals (e.g. migratory birds) are under threat from climate change and need particular monitoring and protection.

v) Increases in *forest productivity* in northern and parts of western Europe should encourage national policy to utilize on a sustainable basis the consequent increasing forest resources and to expand the area under forest cover. In southern and continental Europe, national policies should encourage the development and implementation of adaptive management to maintain the existing forest cover.

vi) Policies to support the adaptation of European *agriculture* to climate change should encourage flexibility of land use, crop production and farming systems. This may require reforming agricultural policy to assist land use change and reforming water markets to encourage more prudent water use. Policy actions should primarily focus on areas where there are long lead times or large investments involved, e.g. for intensive farming systems involving permanent crops, large scale irrigation systems and some livestock systems. More information on effects of climate change at the regional level is needed before actions on specific production systems can be recommended.

vii) Policies for *freshwater fisheries and aquaculture* should be integrated with wider ecosystem-based/watershed-wide management schemes. Biodiversity conservation plans require information on possible shifts in species distribution. Nearly all European marine fisheries are either fully or over-exploited, leaving no safety net for possible climate change effects. An adaptive policy needs to make provisions for (a) reduced levels of production because of ice and snow melt in the north and (b) a move of some of the resources northwards. Faunal shifts resulting from global climate change are likely to increase conflicts between users, and challenge the allocation patterns currently set in the European Common Fisheries Policy.

viii) With respect to *insurance* a concerted effort is required (a) to integrate public resources (e.g. disaster relief) and private resources (e.g. private insurance) to handle extreme events that may become more frequent under climate change, and (b) to focus on vulnerable geographical zones. Such vulnerable zone management should consider the needs of all stakeholders, and include new land development and 'legacy' exposures. A key enabling step is the provision of information on climate change to all the stakeholders. Fiscal policy should be amended to recognise the long-term nature of catastrophe insurance.

ix) Climate change estimates should be incorporated into environmental impact assessments and into investment decisions taken in connection with major *transport and energy* developments and installations. Policies for the monitoring of infrastructure, including bridges and dams, need to be reviewed. Revision of building standards and codes, particularly relating to development in flood risk zones in coastal and riverine hazard areas, is recommended. Investment policies in connection with routine expenditure, such as highway winter maintenance, should be reviewed.

x) Changes in *recreational preferences*, arising at least as a partial result of climate change, may upset the large scale capital transfer from the tourist demand areas of northwest Europe to Mediterranean countries and perhaps to some mountain regions. This would have implications for regional policies. Policy reviews of visitor management strategies associated with increased peak demand at some coastal and rural sites are likely to be needed. Policies to encourage investment in tourist infrastructure to capitalise on new opportunities in new areas should be implemented.

xi) Societies will need to adapt in order to minimise the adverse effects of climate change on *health*, safety, and social well-being. In order to enhance the capacity for the detection of the early health impacts of climate change, research, monitoring and integrated assessment activities should be supported. Potential adaptation options to reduce health impacts include the strengthening of public health programmes, e.g. health education, and vaccination programmes for diseases such as tick-borne encephalitis. Such interventions should be undertaken on the basis of evidence that demonstrates their effectiveness. A co-ordinated pan-European surveillance system needs to be developed that is able to detect changes in incidence/distribution of infectious diseases that are associated with environmental or climate change. There are also substantial implications for policy-making in the various 'upstream' sectors that would mediate some of the effects of climate change on health (water supply, industry, construction, and agriculture). Governments should also address the substantial near-term health benefits of many mitigation policies and technologies in Europe and beyond.

xii) *Coastal zones* will be substantially and progressively altered by climate change, but the magnitude of these changes remains uncertain. Autonomous adjustments will not solve the resulting problems, and policies for coastal areas need to reflect and adapt to these changes as necessary. In particular, there are a number of local, national and EU-wide efforts to promote integrated coastal zone management. These need to be encouraged to strengthen the institutional basis for proactive measures. A challenge across Europe is to develop strategic management policies that allow both continued human utilization and preserve coastal ecosystems under conditions of rising sea levels.

xiii) For *mountain regions* there is a need to raise the awareness of both the general public and policymakers to the real threat of increased natural hazards, such as rockslides, avalanches and floods, which will affect the security of populated regions. In terms of less-populated zones, the vulnerability of the biosphere to change will be a major issue, particularly when attempting to implement segments of Article 2 of the Framework Convention on Climate Change pertaining to ecosystems. Furthermore, because mountains are essentially the 'water towers' of Europe, any changes in rain and snow regimes will significantly impact upon water resources, not only in the source regions but especially in the more populated lowland regions.

Recommendations for research

i) Fundamental to the improvement of *future climate change prediction* is further development and improvement of global climate models. This is a major ongoing international field of research. More specifically, it is also desirable to generate a range of climate change predictions that are consistent with a range of driving scenarios of future atmospheric composition. Methods should be explored for expressing uncertainties related to future climate change within a risk assessment framework. Further research into downscaling of climate information should focus both on improving the techniques themselves and on evaluating their usefulness for application in impact assessment. There is a need to analyse and interpret more systematically the outputs from climate models that relate to extreme climatic events.

ii) *Effects of current weather* can tell us much about the effects of climate change. We need to understand:

- the factors (climatic, technical, economic and cultural) which contribute to the impact of a weather extreme;
- the relationship between sensitivities to present-day weather extremes and the likely sensitivities to future climate change;
- public perceptions of the impact of weather hazards and the short-term management strategies adopted to cope with them; and,
- the suitability, cost and public acceptability of management strategies, both to cope in the short-term with the immediate impacts of the event, and to adapt in the longer-term to lessen the impact of future events.

iii) In order to estimate better the implications of climate change for *water resources and their management* in Europe, research is needed in four priority areas:

- defining scenarios relevant for water sector assessments (including specifically changes in variability over time);
- estimating effects on components of the hydrological system (specifically flood flows, groundwater recharge and water quality);
- estimating the costs and extent of impacts on water resources and hazards under different possible socio-economic futures in Europe and different potential adaptive responses;
- and researching into appropriate techniques for managing water resources in the face of climatic uncertainty.

iv) Research on the implications of climate change for *soil and land resources* should aim to improve understanding of soil processes and their relationship with soil functions, as well as seeking to integrate better our understanding of soils within impacts assessments for other sectors, e.g. water, agriculture, ecosystems, etc. In this way, soils research would contribute better to knowledge on adaptation options to climate change, which is important because of the role that land management plays in moderating soil quality.

v) Research on European *ecosystems* should address the relation between socio-economic trends, land use and ecosystem function more comprehensively than before. In addition, the ecosystem-level underpinnings need to be investigated in a more consistent experimental and modelling framework, particularly for the hydrological regime of complex landscapes, the direct effect of increased CO_2 on individual plants and the whole ecosystem, the role of disturbances such as fire, and the role of pests and pathogens.

vi) For *forestry*, elucidation is needed of the management methods most appropriate for climate change. In particular, a better understanding is needed of how key commercial tree species may interact with climate, pests and management operations to alter yield potentials.

vii) There is a need to explore and develop methods of adaptation to climate change, which also increases the resilience and long-term sustainability of *agricultural production systems* under climate change. This includes developing methods of targeting the use of available genetic resources of plants and animals, studies on diversification of farming systems at regional and local levels, on farm management methods to increase efficiencies of water and nutrient use, and the development of information systems for farmers, including the use of seasonal weather forecasts. There is also a need to study effects on cropping systems and mixed farming systems, some of which have regional specificity and contribute significantly to European rural heritage.

viii) *Fisheries and aquaculture* research need to expand beyond the current single-species approach, and beyond short-term management questions. It should integrate local environmental aspects and the constraints from the regional social fabric of coastal regions, the global market and other economic realities of the industry. Policy research is needed to identify optimal scales of fisheries and aquaculture governance in Europe based on ecosystem-centred approaches to management and the development of adaptive policies.

ix) The *insurance industry* sees the need for major cross-sectoral initiatives to enhance information in the following fields: better access to historical climate data and climate change projections; more detailed climate change predictions, specifically for extreme events in major insurance markets around the world; improved techniques for impact assessment, building on historical experience of extreme events with tools such as geographical information systems (GIS) and simulations; and education about the implications of climate change for all stakeholders in the built environment.

x) As the trans-European *transport* network develops further, research is needed in many European countries on the likely impacts of climate change on the demand for transport and the operation, efficiency and performance of the network. Research is needed that analyses the risk to particular *industries* of climate change and the adaptations and adjustments that may be required, but also identifies new and expanding market opportunities. More research is also needed on how firms perceive climate change and how organisations take into account climatic extremes. The renewable energy industry requires further research into the potential contribution of climate change to the natural variability of wind and solar resources. The construction industry will face new design opportunities, and research on the most appropriate statutory building standards in the EU will be required.

xi) There is an urgent need to conduct further research that translates the expected future climate scenarios in terms of the likely impacts on tourism in the EC. Interactive research that explores the possible response strategy of the *tourism* industry and identifies new and expanding opportunities for the industry is particularly needed. Joint research projects between tourist boards, the private tourism sector and climate experts could be expected to be most productive.

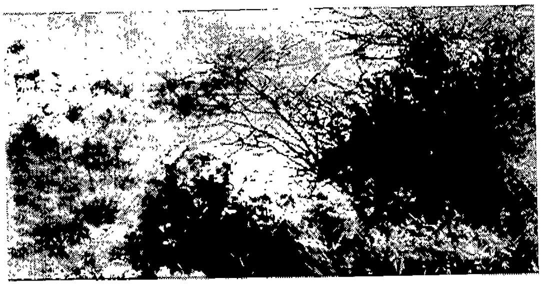
xii) There is a need for baseline research to describe the relationships between weather, climate and *human health*. Such studies will further inform the epidemiological and modelling studies that are needed to estimate future impacts on health. Regional, national and local impact assessments should be undertaken, to identify the means by which the vulnerability of populations and subgroups could be reduced and to select priorities for monitoring. Monitoring systems need to be developed to detect early evidence of changes in disease incidence or distribution that may be related to climate change. There is a need for the development of climate and socio-economic scenarios that are more relevant for health impacts assessment.

xiii) Achieving sustainable management of coastal areas will require a greatly improved knowledge and understanding of the European *coastal system*, including:

- an appropriate GIS database on coastal typology;
- improved scenario development;
- continued process studies and model development;
- continued impact and adaptation assessments.

In particular, there should be a focus on the interactions of climate and other changes in the coastal zone.

xiv) Because of the complex interactions between physical, biological and economic systems in *mountains and uplands*, an integrated approach to impacts research is essential. Particular foci of research should include increases in natural hazards and their impacts on mountain communities, as a result of changes in permafrost, precipitation regimes, vegetation cover, etc. An inventory of potential species extinction as a result of climatic change would help in the development of adaptation strategies, as required by the Framework Convention on Climate Change.



SPECIFIC CONCLUSIONS

Key impacts from current weather

i) Present-day weather extremes impact on natural, social and economic systems in ways which reveal sensitivities and vulnerabilities to climate change in these systems.

ii) The response of these systems to a weather extreme can inform our understanding of how adaptation strategies for climate change will emerge, be implemented, and succeed or fail.

iii) *Drought.* Exceptionally hot, dry conditions can have a devastating impact on the natural environment by reducing water availability in the soil for plant life and in open water bodies for bird and animal life. Outbreaks of algal blooms can make water bodies unusable for recreational purposes. Agriculture and water supply are perhaps the two economic sectors most severely affected by drought, particularly in southern Europe.

iv) *Summer heat waves* in southern Europe can have severe implications for forest fire occurrence and for human health. The extreme temperatures of summer 1998 in Greece are estimated to have led to economic losses of $675 million, with 14 deaths. By late July 1998 forest fires were recorded at 40 separate locations, with temperatures in many regions in excess of 41°C. Even in northern and central Europe, pollution levels may be unacceptably high where hot weather is caused by subsiding anticyclonic air, with knock-on effects for human health in terms of increased asthma attacks and associated hospitalizations.

v) *Mild winters.* Mild winters are beneficial for maritime and central European vegetation species. Northern boreal species such as the Norway spruce have increased stress due to milder winters. With respect to bird and animal life, again we might expect the impact of mild conditions to be beneficial. However, failure to kill off pests and diseases, and to cull the weaker members of the species, may in the end be counter-productive.

vi) *Cold spells.* Freezing conditions and heavy snowfall in winter can severely disrupt human activities in northern and high-altitude regions. Economic sectors which are particularly vulnerable to disruption include transport, the construction and insurance industries. The all-cause death rate rises when temperatures fall.

vii) *Wind storm.* Three very severe storms affected Europe between 1987 and 1990: the events of October 1987, January 25 1990 and February 26 1990. The January 1990 storm (Daria) caused insured losses of around US$5.7 billion (at 1997 prices) and 95 deaths, and in the following month the storm of 26 February (Vivian) caused a further $3.9 billion of insured losses and 64 deaths. Since these events, the frequency and scale of European wind storm has returned to more normal levels.

viii) *Wind storm associated with tidal surge* is a particularly deadly combination, and is epitomized by the event of 1953. The highly unusual track of this storm and a very steep pressure gradient caused severe northerly winds to blow down the North Sea. This, combined with a high spring tide, meant major coastal flooding in the Netherlands and the East Anglian region of the UK, with more than 2000 fatalities. Since then the policy has been to keep the sea out at all costs, and in fact a number of storm surges have occurred with no loss of life.

ix) *River valley floods.* Most recently the most severe negative effects from weather have been from river flooding, particularly in central and eastern Europe. In mid-1998, flooding in Poland, Slovakia and the Czech Republic caused 52 fatalities. In July and August 1997, flooding in the same region and extending into Germany, Austria, Hungary, the Ukraine and Rumania caused over 100 deaths. The value of the economic losses amounted to around US$5 billion, with insured losses of US$940 million. In southern Europe the principal risk is from flash flooding following torrential rain, and from the associated mud slides. Mud slides in the Naples region of Italy in early May 1998 killed 150 people.

Europe in the new millenium

i) The Europe of the next millennium is, by definition, unknowable, although in all likelihood it is likely to be very different to the Europe of today irrespective of the impact of climate change. However, some things are more likely to change in the next millennium than others.

ii) Scenarios are a means of organising the more knowable and the less knowable aspects into a series of 'pictures' of the future. Scenarios can be likened to lenses through which stakeholders can 'view' the future in a consistent and structured manner.

iii) The purpose of scenarios is not to predict the future based on a set of quantified probabilities, but to set out a broad range of *possibilities*. The process of discussing different scenarios may help to inform current decisions, as stakeholders come to better appreciate the possible long-term impact of their activities through a process known as 'social learning'.

iv) Four scenarios of a future Europe, namely (World Markets (WM), Global Sustainability (GS), Provincial Enterprise (PE) and Local Sustainability (LS)), are elaborated, reflecting four possible visions of what may emerge in the next millennium. The scenarios are expressed in terms of changes to the level at which decisions are taken (more global or more local) and the nature of societal preferences (more conservationist or more consumerist) relative to today.

v) The scenarios show that the basic human topography of 'the Europe' in which climate impacts are likely to be experienced in the period through to the 2080s could be very different to the Europe of today. The very political boundaries of a future 'Europe' and the precise allocation of decision-making tasks across the levels of governance within it, vary substantially across the scenarios. Under some of the scenarios the EU as we know it may not even exist at all.

vi) The scenarios make different predictions about the stringency of future climate mitigation strategies and also the means (e.g. voluntary agreements, eco-taxes or regulations) of attaining whatever mitigation targets are agreed upon.

vii) Some sectors of the economy and certain levels of governance will thrive under some of the scenarios but will be inherently more vulnerable under others, *independent* of any additional pressure imposed by the gradually unfolding impact of climate change.

viii) The adaptive strategies adopted to address the vulnerabilities exposed by climate change are likely to differ across the scenarios. For example, building large networks to move water around Europe to address regional shortages is more likely to take place under a world markets scenario than under global sustainability where the accent will be on managing demand.

ix) Finally, the manner in which society values different parts of the human and physical environment is markedly different under the different scenarios. This means that the political attention given to the particular types of climate impact will vary markedly from scenario to scenario, with clear implications for the development of adaptation policy.

The changing climate of Europe

i) Climate change scenarios

Climate change scenarios present coherent, systematic and internally-consistent descriptions of changing climates. These scenarios will typically be used as an input into climate change vulnerability, impact or adaptation assessments, but scenarios are used in many different ways by many different individuals or organisations. No single set of scenarios can satisfy all of these needs. The European ACACIA scenarios presented in this chapter represent a synthesis of current knowledge about future climate change in Europe as well as providing a common scenario framework for this ACACIA assessment. They are consistent with those adopted in the IPCC's forthcoming Third Assessment Report on effects of climate change.

ii) Observed climate change

European temperature trends. Most of Europe has experienced increases in surface air temperature during the twentieth century which, averaged across the continent, amounts to about 0.8°C in annual mean temperature. This warming has been largest over north-western Russia and the Iberian Peninsula and stronger in winter than in summer. An exception is Fennoscandia, which has recorded cooling in both mean maximum and mean minimum temperature during 1910-1995 in winter, but warming in spring and summer. The last decade in Europe (1990-99) has been the warmest in the instrumental record, both annually and for the winter and summer seasons. In recent decades, the warming in annual mean temperature has occurred preferentially as a result of night-time rather than daytime temperature increases. There is some evidence that this reduction in the diurnal temperature range has been associated with increased cloudiness. Warming in surface air temperature is closely related to warming of sea surface temperatures and the twentieth century has seen a warming of surface waters of several tenths of a degree Celsius around much of Europe.

Changes in growing seasons. Increases in growing season length have also been observed in Europe, for example in western Russia and in Fennoscandia. The evidence for longer growing seasons in Europe is also supported by phenological data collected across large parts of central Europe. These point to increases of about 10 days in the average growing season length since the early 1960s.

European precipitation trends. Trends in annual precipitation differ between northern Europe (general wetting) and southern Europe (mainly little change or drying), reflecting a wider hemispheric pattern of contrasting zonal-mean precipitation trends between high and low latitudes. Precipitation over northern Europe has increased by between 10 and 40 per cent in the twentieth century, whereas some parts of southern Europe have dried by up to 20 per cent. There is large decadal-scale variability in drought frequency in Europe, with the 1940s and early 1950s experiencing widespread and severe droughts, a pattern repeated in 1989 and 1990.

Changes in variability. Analyses of trends in extreme weather events in Europe have generally been limited to national studies, making it difficult to provide a Europe-wide overview of changes in hot/cold day frequencies, precipitation intensities or gale frequencies. One important cause of interannual, and perhaps interdecadal, climate variability in Europe, particularly in winter, is the North Atlantic Oscillation (NAO). During the 1980s and 1990s, the NAO Index has generally been above its long-term mean, a fact that has been responsible for relatively mild and wet winters during this period over much of northwest Europe.

iii) Future climate change

Natural climate variability. European climate will vary naturally over future decades, with or without substantial human influence on climate. Model simulations suggest that, regionally, natural variations in 30-year mean climate (expressed as ±2 standard deviations of the mean) could be as large as ±10 and ±15 per cent for winter and summer precipitation, respectively, and more than 1°C and up to 0.8°C for winter and summer temperature, respectively.

Global climate scenarios. For a comprehensive assessment of the impact and implications of climate change it is necessary to apply a number of climate change scenarios that span a reasonable range of the likely future climate change distribution. The ACACIA scenarios are defined at a global scale by making choices about future greenhouse gas emissions and the climate sensitivity. We use the four preliminary marker emissions scenarios generated by the IPCC Special Report on Emissions Scenarios (SRES) and climate sensitivities ranging from 1.5° to 4.5°C. These choices yield four global climate scenarios referred to as B1-low, B2-mid, A1-mid and A2-high. These four climate futures warm at a rate of between 0.1° and 0.4°C per decade. Atmospheric CO_2 concentrations reach 550ppmv as early as 2050 under the A2-high scenario, but not until 2100 under the B1-low scenario. The ACACIA scenarios do not consider the highly uncertain effect on future climate of changing concentrations of atmospheric aerosols.

European temperature scenarios. For substantial parts of Europe, warming under the B1-low scenario by the 2020s remains below the two standard deviation threshold of modelled natural variability, and even by the 2050s summer warming over Poland and Belarus does not exceed this magnitude. For the other three scenarios, however, the greenhouse gas-induced warming exceeds what might possibly occur due to natural climate variability. For temperature, inter-model agreement in winter is greatest over southern Europe, whereas in summer this region shows the greatest level of disagreement between the simulations. The greatest warming (>5°C) occurs in the A2-high scenario for the 2080s and in winter over central and north-eastern Europe. This Median warming, however, has an inter-model range larger than ±3°C, suggesting large differences between models.

European precipitation scenarios. The general pattern for precipitation change over Europe is for widespread increases in winter precipitation and a marked contrast in summer between northern Europe (wetting) and southern Europe (drying). Not many of these changes for the earlier time periods (2020s and 2050s) and for the scenarios with slower rates of global warming (B1, B2 and A1) are greater, however, than what might possibly occur due to natural climate variability. In some regions the inter-model range of seasonal precipitation changes is larger than the median change, implying that sign differences exist between precipitation changes simulated by different climate models.

Seasonal temperature extremes. 'Cold' winters become very much rarer by the 2020s and disappear almost entirely by the 2080s across large areas of Europe, especially for the A2-high scenario. 'Hot' summers, in contrast, become very much more frequent and by the 2080s under the A2-high scenario nearly every summer is hotter than the 1-in-10 year 'hot' summer as defined under present climate. Even by the 2020s for a country like Spain, 'hot' summers become four to five times more frequent than at present.

Sea-level changes. Global warming is expected to result in a worldwide rise in sea-level. Our scenarios suggest a rise in global-mean sea-level by the 2050s of between 13 and 68cm, although we make no allowance for regional differences brought about by ocean and atmosphere circulation changes. These estimates also makes no allowance for natural vertical land movements. Owing to tectonic adjustments following the last glaciation, there are regional differences across Europe in the natural rates of relative sea-level change. While much of central and southern Europe is slowly sinking (typically by 5cm by the 2080s), much of northern Europe is rising out of the ocean. Consideration of the impacts of sea-level rise also requires some assessment of the changing storm environment and the ways in which mean sea-level rise, storm regimes and offshore topography may combine to alter the return periods of high tide-levels.

iv) Uncertainties

To estimate how much confidence we have in climate change predictions we have to examine the sources of uncertainty in our predictions. There are different reasons why we are uncertain about different input or output variables. These reason include: missing components or errors in input data: systemic unpredictability: unknown or erroneous model structure or parameters: changing model structure or parameters over time. The three main sources of uncertainty addressed in the ACACIA scenarios are: future greenhouse gas emissions, the climate sensitivity and the regional climate response to planetary warming. It is also acknowledged, however, that there are low probability, non-linear feedbacks that could produce future climate and sea-level changes that lie outside the range of the ACACIA scenarios.

The likely effects of a changing climate in Europe

Water resources

a) Climate change is only one of many pressures facing water resources and their management in Europe over the next few years and decades.

b) Although there is variability between scenarios, there is a general suggestion that climate change will result in an increase in annual streamflow in northern Europe, and a decrease in the south.

c) In maritime and Mediterranean areas, climate change generally results in an increasing range in flows through the year, as increases in precipitation are concentrated in winter. In areas currently receiving substantial snowfall, a rise in temperature means an increase in the amount of precipitation that falls as rain, and therefore a shift in the season of peak flows from spring, after snowmelt, to winter. This occurs across much of eastern and mountainous Europe. In the far north and east of Europe the rise in temperature is not sufficient to convert snow to rain, so the timing of streamflow is relatively unaffected in these areas.

d) Climate change is likely to lead to a general increase in the risk of summer drought in Europe, particularly in the south. But in many areas this may be offset by increased precipitation and streamflow during winter (leading overall to a reduction in drought risk if there is sufficient storage for the extra winter runoff).

e) Climate change is likely to lead to an increase in flood risk across most of Europe. In some regions - where the snowmelt peak is replaced by a winter peak - the season of maximum flood risk will change.

f) River water quality is likely to be generally adversely affected by climate change, particularly where quality is already under threat.

g) The impact of climate change is a function not only of the hydrological changes, but also of the characteristics of the water management system. They are therefore very difficult to generalise in quantitative terms. However, it is likely that there will be increasing uncertainty in the reliability of water supplies in many areas of Europe (with implications also for power generation), an increased risk of water quality problems, and an increased flood threat. Navigation on the major European waterways is also likely to be affected.

h) Adaptation to climate change will involve a combination of supply-side (altering the water) and demand-side (altering the demand for the resource or exposure to hazard) actions. A wide range of supply-side approaches is available to the water sector, and some organisations in some countries are explicitly considering the effects of climate change in long-term resource planning. However, few agencies are used to planning water resources in the face of uncertainty. Demand-side approaches have the potential to reduce vulnerability to climate change, but are currently less widely pursued. However, there is an increasing interest in Europe in demand-side strategies for water management. There are differences in adaptive capacity between the managed and unmanaged parts of the water environment, and planning lead times vary between sectors.

i) Uncertainty in the climate change scenarios is generally the largest source of uncertainty in climate impact analysis in the water sector, but in some sectors additional uncertainty arises from a lack of knowledge of the scientific processes translating climate change to hydrological effect. Also, the impacts of change in some sectors - particularly river and wetland environments - may be very difficult to estimate.

Soil and land resources

a) Climate change will impact directly and, through land use change, indirectly on a wide range of soil processes and properties that will determine the future ability of land to fulfill the key functions that are important for all terrestrial ecosystems as well as many socio-economic activities underpinning the well-being of society.

b) It is likely that all land areas will be affected in some way by climate change through the influence of a wide range of different processes, and many of the soils of Europe are likely to suffer a loss of soil function because of this.

c) Soil organic matter (SOM) decomposition rates vary widely between different soil carbon pools, and between different locations because of water and temperature effects. However, it is likely that climate change will increase the rate of decomposition, above the rate of return of carbon to soils arising from increased vegetation growth (stimulated by CO_2), so that SOM levels will diminish in many parts of Europe. This is most likely to occur in the cooler regions of Europe, where SOM decomposition is currently limited by temperature.

d) Evidence for the impact of climate change on soil nutrients is conflicting. It is likely, however, that total soil nitrogen contents will diminish under a warmer and drier climate as a result of declining SOM contents, the stimulation of plant growth and nitrogen uptake because of the CO_2 effect, ammonia volatilisation, nitrate leaching and increased N_2O emissions.

e) There is great uncertainty surrounding the response of soil organisms and thus, soil biodiversity, to climate change and the potential effects of these responses at the ecosystem level. Most soil biota have relatively large temperature optima which suggests they are unlikely to be adversely affected by climate change, although some evidence exists to support changes in the balance between soil functional types.

f) Land degradation processes, such as salinisation, peat wastage (and associated acid sulphate conditions) and soil erosion, are all likely to increase in the future under more arid conditions. However, the magnitude of any change will vary greatly between geographic locations, and will depend strongly on changes in rainfall distributions and intensity, as well as changes in land use.

g) Drier climatic conditions will lead to increases in the frequency and size of crack formation in soils with high clay contents. This will result in the more rapid movement of water and solutes from the soil surface to substrata or drainage installations (bypass flow) with associated increased pollution risks, as well as leading to the damage of building through subsidence.

h) Present policy for the protection of soil and land resources appears to be inadequate, given the wide range of current issues, and the likely deterioration in land quality arising from climate change in the future. Thus, the implementation of policy that aims to preserve the quality of soil and land resources, both in the present and in the future, is now timely. Such policies would need to be regionalised, targeting specific issues within different European locations.

Ecosystems

a) Most northern and western European ecosystems are temperature-limited, while eastern and southern ecosystems depend more directly on moisture availability. Warming and CO_2 enrichment (as well as nitrogen deposition from atmospheric pollution) are likely to increase net productivity in most European ecosystems (even where rainfall might be reduced), but significant non-linear factors could modify this pattern. Due to temperature-enhanced soil respiration, increased productivity does not necessarily result in higher storage of carbon in ecosystems.

b) The distribution of potentially natural vegetation in Europe is likely to change, leading to a northward displacement of boreal forests, northward-expanding broad-leaved temperate forests in eastern Europe and to a likely expansion of frost-intolerant species from the northern Iberian peninsula into the British Isles. This redistribution may be delayed or accelerated by topography or land use. Changes will likely result in altered vegetation composition in nature reserves. Semi-natural vegetation may also be affected, depending on management.

c) Fire disturbances are likely to become more frequent and severe in the Mediterranean region. In other areas, disturbance regimes (drought, fire, storms, insects) may change in unexpected ways – the sensitivity of ecosystems to such changes is high.

d) Plant and animal species diversity at the landscape level is influenced by regional climate as well as by local factors (land use, pollution etc.) – the expected rapid changes of vegetation composition due to climate change are likely to result in the loss of species in some areas.

e) The response of most animal communities depends on the fate of specific habitats. For example, loss of subarctic tundra and/or wetlands due to thermokarst, sea level rise or shrub encroachment could threaten migratory bird populations.

f) Given the uncertainties with respect to future atmospheric CO_2 levels and associated regional climate scenarios, the sensitivity of European ecosystems can only be determined in *semi-quantitative measures*. Land use in Europe is changing rapidly, mostly due to changes in agricultural intensity, and the regional signal of possible climate change-driven ecosystem changes can presently not be detected against the background of land use change and atmospheric pollution.

Forestry

a) The genetic variability of most common tree species is probably large enough to allow them to acclimatize to expected changes in average temperatures and precipitation. Problems may be encountered, however, with changes in the frequency and amplitude of extreme events such as drought, wind and spring and summer frost.

b) In the Mediteranean region and continental Europe, increased droughts and fires may be the major risk for forests. In western Europe, the risk of these will also increase. In northern Europe, increases in precipitation are projected to be sufficiently large to compensate for increased evapotranspiration, and there is no major risk for forest survival.

c) Increase in growth has been recorded recently in Austria, Denmark, France, Germany, Slovenia, Sweden, and Switzerland, with possible increases also occurring in Portugal and Spain. This is assumed to be a consequence of observed higher temperatures and increased ambient levels of CO_2. Model computations support this assumption, but confirmation from experiments is still limited. A greater dominance of deciduous tree species, even in northern Europe, may result from this trend.

d) In northern Europe the widespread use of natural regeneration in forest management provides substantial genetic potential to adapt to climate change. In other parts of Europe, increased drought may result in uncertainties in natural regeneration. In these conditions, the preference of tree provenance of more southern origin and wider spacing in plantations may be appropriate adaptations. Throughout Europe, regular management with shorter rotation will enhance the turnover of the current tree populations leading to the speedier introduction of more resistant tree species.

e) In northern Europe, increased precipitation, cloudiness and rain days, and the reduced duration of snow cover and soil frost would adversely affect forest work and timber logging and lead to lower profitability of forest production. Increased wind damage may more frequently increase unscheduled cuttings with increased costs and also disturb timber markets.

f) Some insect and pest populations are expected to increase but the extent to which they may be held in check by predators or require management control is not known. Currently non-damaging organisms may reach pest level and invading species may become dangerous. Conditions favouring the spread and epidemic status of pathogens are also poorly known. Interactions with wildlife generally and effects on biodiversity are poorly known.

Agriculture

a) Several economic, cultural, political, technological and environmental factors affect agricultural production in Europe. Agriculture is most vulnerable to unfavourable climatic conditions in those areas where agriculture is most temperature-limited (northern Europe) and most moisture-limited (parts of eastern and southern Europe). Agriculture along the Atlantic coast is also restricted by high rainfall. Prevailing temperature, incoming solar radiation and rainfall are the main climatic factors that determine agricultural production, either directly or through effects on nutrient and water availability, and control of weeds, pests and diseases.

b) Crop production systems are affected both by climate change and by change in CO_2 concentration. Warming is expected to lead to a northward expansion of suitable cropping areas and a reduction of the growing period of determinate crops (e.g. cereals), but an increase for indeterminate crops (e.g. root crops). Increasing atmospheric CO_2 concentrations will directly enhance plant productivity and also increase water use efficiency.

c) Livestock systems will be affected, directly by change in frequency of extreme weather events (i.e. animal health, growth and reproduction), and indirectly by changes in productivity of crop systems (e.g. pastures and forage crops), and through requirements for housing.

d) Agriculture is particularly sensitive to climatic variability in the most northern and southern regions of Europe, and changes in the geographical pattern of climate is likely to alter potential agricultural productivity. In northern areas climate change may produce positive effects on agriculture through introduction of new crop species and varieties, higher crop production and expansion of suitable areas for crop cultivation. The disadvantages may be determined by an increase in need for plant protection, risk of nutrient leaching and accelerated breakdown of soil organic matter.

e) In southern areas of Europe the benefits of the projected climate change will be limited, while the disadvantages will be predominant. The increased water use efficiency caused by increasing CO_2 will compensate for some of the negative effects of increasing water limitations. The possible increase in water shortage and extreme weather events may cause lower harvestable yields, higher yield variability and a reduction in suitable areas of traditional crops. The increase in water shortage may be caused by reduced rainfall, higher evapotranspiration and reduced availability of irrigation water.

f) Short-term adjustments to mitigate negative effects of climate change on agriculture include changes in agronomic practices (e.g. changes in crop varieties, dates of planting and harvesting), changes in use of external inputs (fertilisers, pesticides, growth regulators etc.), and practices to conserve moisture (e.g. introduction of conservation tillage methods and better irrigation management).

g) Long-term adaptations to climate change include changes in land use (to optimise or stabilise production), development of suitable crop types (i.e. to increase resistance to heat, water, weed, pest or disease stresses), substitution of crops (e.g. subtropical or tropical crops in the southern regions, maize and sunflower in the northern regions, cereals and vegetables in the outmost northern regions), modification of microclimate, more efficient irrigation systems, and changes in farming systems (e.g. mixed versus specialised arable and livestock systems).

Fisheries

a) Marine fisheries contribute between 0.01% and 1% of EU GDP. Their importance has been steadily decreasing, with diminishing returns as a result of chronic overfishing and reduced employment opportunities resulting from increased production efficiency. By contrast, recreational fisheries and aquaculture, although relatively minor activities, are increasing in socio-economic importance in fresh and marine waters.

b) The younger age groups of fish are highly sensitive to changes in water temperature, either side of an evolutionary determined optimum. Short-term climate variability affects both the geographical distributions of fish and shellfish species and their productivity. The adaptability of the fisheries sector (capture and culture) to climate variability is currently reduced by market demand, environmental pressure, unsustainable extraction/ production practices and a rigid policy framework.

c) Changes in aquatic biodiversity and fish production are two key impacting aspects of climate change on the future of the European fisheries sector. The most vulnerable species are those with juvenile stages in freshwaters - including migratory salmonid, alewives, and sturgeon species - where air temperature rise will lead to local extinction in watersheds at the edges of the current ranges. Productivity will generally be affected positively by a temperature increase in the north of the region, but a possible breakdown of the thermo-haline circulation in the North Atlantic caused by polar ice melt may dramatically cool ocean water temperatures and lead to fisheries collapse.

d) Resource scarcity and environmental change are threatening most European fisheries with collapse. Assuming that sustainable management regimes can be introduced, adaptive options need more industry participation to emerge, as well as more coherence between European agriculture, environment, fisheries and regional development policies.

e) Changes in fisheries diversity and productivity will affect development opportunities of communities in coastal areas, and around large water bodies. In the current policy context, any decrease in productivity or changes in species distribution are likely to increase conflicts between aquatic resource users.

f) Some key uncertainties and unknowns about the response of the fisheries sector to global climate change arise from the prevalent production driven policy and lack of ecosystems approach to fisheries research and management. Policy research is urgently needed to reconcile market forces and environmental sustainability and foster adaptive management plans.

Insurance

a) The insurance sector is sensitive to changing patterns of extreme weather events, particularly through their impact on property damage. Socio-economic factors are increasing this exposure, due to factors such as increasing property values located in hazardous areas.

b) There are currently large differences between countries in the application of insurance to managing natural hazards. It is expected that practices will converge for economic reasons. Climate change may accelerate this process.

c) Major impacts could arise from coastal flooding or from windstorm damage in northwest Europe. Locally events can be catastrophic, but often the insurance industry does not provide cover, for example, for standing crops or against flood in most of Europe. Outside Europe, the sector is exposed to extreme events, particularly to hurricane activity in the USA.

d) It is unclear how the pattern of extreme events will change, because GCMs cannot yet provide information at the meso-level. It is almost certain that climate changes will have a negative impact due to the strongly non-linear relationship between weather intensity and property damage.

e) It is improbable that climate changes will threaten the overall solvency of the European insurance industry. However, regional insurers may be endangered, as has happened in the USA.

f) Adaptive responses fall into four categories: 1) pricing, which is often difficult to implement for competitive or regulatory reasons and owing to the lack of sufficient information about future risk; 2) risk transfer, where there is scope to spread insurance risk into the wider financial markets, e.g. through derivatives, but such instruments are in their infancy; 3) limitation, which would safeguard insurers' interests but confer costs on other stakeholders; 4) loss control, which has considerable potential to reduce vulnerability for insured and uninsured exposures. The insurance industry has significant resources which could be utilised effectively even where risk is not transferred. However, the response will require a great increase in co-operation between stakeholders.

Transport, energy and other industries

a) Transport is a derived demand and is highly dependent upon changes in other sectors of the economy.

b) The degree to which predicted levels of climate change affects transportation is very dependent upon the extent of other changes in the transport system, which in themselves could be of greater significance and importance than those arising from climate change.

c) Transport is particularly sensitive to many extremes of weather, especially wind, snow and frost, some of which (e.g. windstorms) may become more frequent as a result of climate change.

d) There are likely to be some positive effects of climate change for transportation, for example, a reduction in parts of western Europe in the number of days with frost and lying snow, which can lead to disruption and accidents, especially on the road network.

e) Fewer severe winters would be beneficial to manufacturing industry, reducing disruption at all stages from the supply of raw materials through processing to the marketing of finished goods. An increase in the frequency of hot dry summers could disrupt some industrial processes using large quantities of water. There may be some absolute limiting factors in some countries such as a lack of water for power stations which can only be overcome by massive capital investment or new technology.

f) Industry operates in a global market place and changes in climate outside Europe could be as important as climate change within Europe.

g) Increasing temperatures will have a direct impact on energy use in both domestic and industrial sectors and affect heating and cooling requirements. Increases in space cooling demand, and decreases in space heating demand are to be expected. The possible impact of climate change on energy demand is sufficiently great that this factor ought to be taken into account when long-range energy forecasting exercises are carried out.

Tourism and recreation

a) Tourism has a strong international dimension and is sensitive to any change of climate that alters the competitive balance of holiday destinations.

b) Tourism and recreational pursuits are voluntary activities and subject to rapid changes of fashion. Climate is a primary motivating factor that is taken into account, particularly in relation to longer holidays, in deciding location and timing.

c) Higher temperatures are likely to stimulate tourism and recreational activities outdoors in northern Europe with a lengthening of the main season for outdoor recreation.

d) Winter sports centres across Europe will be increasingly at risk from shorter seasons and less reliable snow cover, especially those at lower altitudes.

e) Higher sea surface temperatures around European coasts should extend the length of the sea bathing season in areas where this activity already takes place and also extend summer sea bathing to more northerly resorts.

f) The increased frequency of summer heatwave conditions in southern Europe is likely to have an adverse effect on the attractiveness of some Mediterranean areas as the location for the traditional summer package holiday.

Human health

a) Climate change poses a range of risks to human population health. Health impacts would occur via a variety of mechanisms.

b) There is little clear evidence of changes in health outcomes having occurred in response to observed recent warming trends in Europe. There is a lack of formal research in this area and most assessments rely on expert judgement. There is some evidence that the distribution of tick vectors has moved north in Sweden concomitant with observed warming.

c) Changes in the frequency of temperature extremes and stagnation episodes would entail increases in thermal stress and air pollution episodes, and their well-documented impacts on mortality and morbidity, especially in the elderly.

d) Less severe cold weather would reduce the excess winter mortality, especially in northwest Europe.

e) The increased risk of coastal and riverine flooding has important implications for health. Floods can cause deaths, injuries, and outbreaks of infectious disease and psycho-social problems.

f) Some vector-borne diseases may expand their range north within Europe (e.g. leishmaniasis, tick-borne encephalitis). It is unlikely that 'tropical' diseases such as malaria or dengue would become re-established in western Europe if control measures are maintained – however, the risk of localised (autochthonous) outbreaks of malaria may increase.

g) Increases in temperature may exacerbate the current trend of increases in cases of food-borne illness. Mechanisms already in place, or planned, are likely to counter the increased risk of diseases associated with microbiological contamination of the water supply.

Coastal zones

a) Sea levels have risen around much of Europe combined with subsidence and falling land levels, while storm frequency and track have shown significant interdecadal variability in northwestern Europe. These ongoing factors are already important contributors to the problems of Europe's coasts, particularly flood risk, coastal erosion and coastal squeeze.

b) However, climate change and variability is just one of the pressures facing coastal zones and their management over the next few decades.

c) The sea-level rise scenarios considered here will result in an increase in flood risk for coastal lowlands and increased rates of coastal erosion for cliffs and beaches. Quantitative analysis suggests that flood risk will increase much more in southern Europe. Increases in storminess (due to climate variability and/or long-term changes) would also increase storm damage and flood risk.

d) The sea-level rise scenarios considered here would also result in the rapid degradation of saltmarsh and intertidal ecosystems. The Baltic and Mediterranean coasts are most vulnerable due to their low tidal range and such ecosystems could be largely eliminated in these areas by the 2080s, given the A2-high scenario.

e) The actual impacts of climate change will depend both on the magnitude of climate change and the human adaptation to that change. Many of the impacts of sea-level rise could be avoided or managed effectively given proactive measures today. This suggests the need to increase the capacity to manage the coast at short, medium and long time scales, particularly a focus on long-term coastal planning, as well as more detailed research on the potential impacts and adaptation measures to climate change. This research would have to address appropriate adaptation options given the large uncertainties that exist concerning future climate and most other relevant factors.

f) Losses and changes to coastal ecosystems are one problem where adaptation measures appear more limited, particularly in the most threatened areas. The natural response is for onshore migration of the wetlands with rising sea levels, but this is stopped by rigid sea defences producing a coastal squeeze. Managed retreat or realignment is appropriate if low-grade agricultural land is landward of the defence, but it is more difficult when development exists landward of the defence. This shows that there is often a conflict between sustaining socio-economic activity and the ecological functioning of the coastal zone in Europe under rising sea levels which needs to be explicitly addressed by coastal management.

Mountain regions

a) Observational evidence of past changes in mountain regions (upward migration of plant species, glacier retreat), particularly in the Alps, suggests that climatic changes occurring in the latter part of the 20th century exceed the range of recent variability.

b) Hydrological systems will be affected by shifts in precipitation regimes, soil moisture, and changes in forest and ecosystem distribution. The consequences will be felt far downstream of the mountains themselves, in populated lowland regions where water is required for industry, agriculture, transportation and domestic purposes.

c) Cryospheric systems are amongst the most sensitive to warming. Glacier mass balance will be negatively influenced by warmer temperatures, and 50 - 90 % of alpine glaciers could disappear by the end of the 21st century. The lower and southern limits of discontinuous permafrost will shift upwards and northwards, respectively, followed by degradation and local extinction of species and habitats which depend on 'cold soils'.

d) The snowline rises by 100-150m for every degree of warming. Decreasing snowpack and a shorter snow season affects the timing and amount of runoff in river basins, and has economic consequences in terms of winter tourism.

e) Similarly, warming will cause an upward shift in tree-lines and vegetation belts. There is some evidence that this upward migration will be slower in the Alps than in the Scandes.

f) Decreased slope stability and enhanced episodes of rockfalls, mudslides, avalanches, etc., will occur as a result of the degradation of high-mountain permafrost and shifts in precipitation patterns. This will lead to increased spatial heterogeneity, locally higher species richness and a more herbaceous and heliophilous flora, due to the gaps formed by the more active slope processes.

g) Increased fire hazards in a warmer, drier climate (particularly in the Mediterranean zone), could affect populated regions in and close to certain mountain regions of Italy, Spain, Turkey, Greece, and France. Vegetation in the south-facing slopes, and particularly in lime-rich regions, will yield to more xerophytic and oro-mediterranean flora.

h) Species may become extinct at the tops of mountains because of climate change and species competition, due to the competitive exclusion by more thermophilic species migrating upwards. This may also take place at ecotone boundaries for rare and geographically, altitudinally, and environmentally-restricted species.

i) Climatic warming will cause high alpine fell-field vegetation to be rapidly colonized by mid-alpine species, whereas mid-alpine snowbed vegetation will decrease, due to the changed hydrology and much less snowcover (both in terms of depth and duration).

Summary for Policymakers

Land Use, Land-Use Change, and Forestry

A Special Report of the Intergovernmental Panel on Climate Change

This summary, approved in detail at IPCC Plenary XVI (Montreal, Canada, 1–8 May 2000), represents the formally agreed statement of the IPCC concerning current understanding of land use, land-use change, and forestry activities and their relationship to the Kyoto Protocol.

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1. Introduction

1. Under Article 3.1 of the Kyoto Protocol, the Annex I Parties have agreed to limit and reduce their emissions of greenhouse gases between 2008 and 2012.

2. The Kyoto Protocol makes provision for Annex I Parties to take into account afforestation, reforestation, and deforestation (ARD) and other agreed land use, land-use change, and forestry (LULUCF) activities in meeting their commitments under Article 3.

3. To implement the Kyoto Protocol, issues related to LULUCF will have to be considered. Relevant issues may include for example:

    - Definitions, including land-use change, forests, forestry activities, including afforestation, reforestation, and deforestation, carbon stocks, human-induced, and direct human-induced;
    - Methodological issues, such as:
        - ➢ Rules for accounting for carbon stock changes and for emissions and removals of greenhouse gases from LULUCF activities, including:
            - – Which carbon pools to include;
            - – How to implement "since 1990," "direct human-induced," and "human-induced";
            - – How to address the risks and effects of events such as fires, pest outbreaks, and extreme meteorological events; baselines; permanence; interannual and decadal climate variability; and leakage;
            - – Accuracy, precision, and uncertainties in tracking carbon stocks and greenhouse gases;
        - ➢ Approaches, such as geo-referencing and statistical sampling, associated with identifying lands with activities defined under Article 3.3, accepted under Article 3.4, or associated with project-based activities under the Kyoto Protocol, and measuring and estimating changes in carbon stocks and greenhouse gases;
        - ➢ Verification procedures;
    - Determination of how and which additional activities pursuant to Article 3.4 are included;
    - How to link the first and subsequent commitment periods;
    - Determination of how and which project-based activities are included;
    - What improvements, if any, are needed to the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories and the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories;
    - What are the implications of and what, if any, national and/or international sustainable development criteria could be associated with Articles 3.3 and 3.4 and project-based activities.

4. Therefore, to assist the Parties to the Protocol, this Summary for Policymakers (SPM) provides relevant scientific and technical information in three parts:

    - Part I describes how the global carbon cycle operates and provides a context for the sections on ARD and additional human-induced activities;
    - Part II addresses important issues regarding definitions and accounting rules. It identifies a range of options and discusses implications and interrelationships among options;
    - Part III provides information that governments might find useful in considering these issues:
        - ➢ An assessment of the usefulness of models and of the usefulness and costs of ground-based and remotely-sensed measurements and of monitoring techniques for assessing changes in carbon stocks;
        - ➢ The near-term (first commitment period) potential for carbon stock changes/accounting of activities in Annex I countries and globally;
        - ➢ Issues of special significance to project-based activities;
        - ➢ An evaluation of the applicability of the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories for national and project-level accounting in light of the Kyoto Protocol;
        - ➢ Implications of Articles 3.3 and 3.4 and project activities on sustainable development (i.e., socioeconomic and environmental considerations).

Part I

2. Global Carbon Cycle Overview

5. The dynamics of terrestrial ecosystems depend on interactions between a number of biogeochemical cycles, particularly the carbon cycle, nutrient cycles, and the hydrological cycle, all of which may be modified by human actions. Terrestrial ecological systems, in which carbon is retained in live biomass, decomposing organic matter, and soil, play an important role in the global carbon cycle. Carbon is exchanged naturally between these systems and the atmosphere through photosynthesis, respiration, decomposition, and combustion. Human activities change carbon stocks in these pools and exchanges between them and the atmosphere through land use, land-use change, and forestry, among other activities. Substantial amounts of carbon have been released from forest clearing at high and middle latitudes over the last several centuries, and in the tropics during the latter part of the 20th century. [1.1.1.2][1]

6. There is carbon uptake into both vegetation and soils in terrestrial ecosystems. Current carbon stocks are much larger

[1] Numbers in brackets at the end of this and subsequent paragraphs indicate relevant sections of the Special Report containing details.

Table 1: Global carbon stocks in vegetation and soil carbon pools down to a depth of 1 m.

Biome	Area (10^9 ha)	Global Carbon Stocks (Gt C)		
		Vegetation	*Soil*	*Total*
Tropical forests	1.76	212	216	428
Temperate forests	1.04	59	100	159
Boreal forests	1.37	88	471	559
Tropical savannas	2.25	66	264	330
Temperate grasslands	1.25	9	295	304
Deserts and semideserts	4.55	8	191	199
Tundra	0.95	6	121	127
Wetlands	0.35	15	225	240
Croplands	1.60	3	128	131
Total	15.12	466	2 011	2 477

Note: There is considerable uncertainty in the numbers given, because of ambiguity of definitions of biomes, but the table still provides an overview of the magnitude of carbon stocks in terrestrial systems.

in soils than in vegetation, particularly in non-forested ecosystems in middle and high latitudes (see Table 1). [1.3.1]

7. From 1850 to 1998, approximately 270 (+ 30) Gt C has been emitted as carbon dioxide (CO_2) into the atmosphere from fossil fuel burning and cement production. About 136 (+ 55) Gt C has been emitted as a result of land-use change, predominantly from forest ecosystems. This has led to an increase in the atmospheric content of carbon dioxide of 176 (+ 10) Gt C. Atmospheric concentrations increased from about 285 to 366 ppm (i.e., by ~28%), and about 43% of the total emissions over this time have been retained in the atmosphere. The remainder, about 230 (+ 60) Gt C, is estimated to have been taken up in approximately equal amounts in the oceans and the terrestrial ecosystems. Thus, on balance, the terrestrial ecosystems appear to have been a comparatively small net source of carbon dioxide during this period. [1.2.1]

8. The average annual global carbon budgets for 1980–1989 and 1989–1998 are shown in Table 2. This table shows that the rates and trends of carbon uptake in terrestrial ecosystems are quite uncertain. However, during these two decades, terrestrial ecosystems may have served as a small net sink for carbon dioxide. This terrestrial sink seems to have occurred in spite of net emissions into the atmosphere from land-use change, primarily in the tropics, having been 1.7 ± 0.8 Gt C yr^{-1} and 1.6 ± 0.8 Gt C yr^{-1} during these two decades, respectively. The net terrestrial carbon uptake, that approximately balances the emissions from land-use change in the tropics, results from land-use practices and natural regrowth in middle and high latitudes, the indirect effects of human activities (e.g., atmospheric CO_2 fertilization and nutrient deposition), and changing climate (both natural and anthropogenic). It is presently not possible to determine the relative importance of these different processes, which also vary from region to region. [1.2.1 and Figure 1-1]

9. Ecosystem models indicate that the additional terrestrial uptake of atmospheric carbon dioxide arising from the indirect effects of human activities (e.g., CO_2 fertilization and nutrient deposition) on a global scale is likely to be maintained for a number of decades in forest ecosystems, but may gradually diminish and forest ecosystems could even become a source. One reason for this is that the capacity of ecosystems for additional carbon uptake may be limited by nutrients and other biophysical factors. A second reason is that the rate of photosynthesis in some types of plants may no longer increase as carbon dioxide concentration continues to rise, whereas heterotrophic respiration is expected to rise with increasing temperatures. A third reason is that ecosystem degradation may result from climate change. These conclusions consider the effect of future CO_2 and climate change on the present sink only and do not take into account future deforestation or actions to enhance the terrestrial sinks for which no comparable analyses have been made. Because of current uncertainties in our understanding with respect to acclimation of the physiological processes and climatic constraints and feedbacks amongst the processes, projections beyond a few decades are highly uncertain. [1.3.3]

10. Newly planted or regenerating forests, in the absence of major disturbances, will continue to uptake carbon for 20 to 50 years or more after establishment, depending on species and site conditions, though quantitative projections beyond a few decades are uncertain. [1.3.2.2]

11. Emissions of methane (CH_4) and nitrous oxide (N_2O) are influenced by land use, land-use change, and forestry activities (e.g., restoration of wetlands, biomass burning, and fertilization of forests). Hence, to assess the greenhouse gas implications of LULUCF activities, changes in CH_4 and N_2O emissions and removals — the magnitude of which is highly uncertain — would have to be considered explicitly. There are currently no reliable global estimates of these emissions and removals for LULUCF activities. [1.2.2, 1.2.3, 3.3.2]

***Table 2:** Average annual budget of CO_2 for 1980 to 1989 and for 1989 to 1998, expressed in Gt C yr^{-1} (error limits correspond to an estimated 90% confidence interval).*

	1980 to 1989	1989 to 1998
1) Emissions from fossil fuel combustion and cement production	5.5 ± 0.5	6.3 ± 0.6[a]
2) Storage in the atmosphere	3.3 ± 0.2	3.3 ± 0.2
3) Ocean uptake	2.0 ± 0.8	2.3 ± 0.8
4) Net terrestrial uptake = (1) – [(2)+(3)]	0.2 ± 1.0	0.7 ± 1.0
5) Emissions from land-use change	1.7 ± 0.8	1.6 ± 0.8[b]
6) Residual terrestrial uptake = (4)+(5)	1.9 ± 1.3	2.3 ± 1.3

[a] Note that there is a one-year overlap (1989) between the two decadal time periods.
[b] This number is the average annual emissions for 1989–1995, for which data are available.

Part II

3. Issues Associated with Definitions

12. For purposes of this Special Report, in a given land area and time period, a full carbon accounting system would consist of a complete accounting for changes in carbon stocks across all carbon pools. Applying full carbon accounting to all land in each country would, in principle, yield the net carbon exchange between terrestrial ecosystems and the atmosphere. However, the Kyoto Protocol specifies, among other things, that attention focus onto those land areas subject to "direct human-induced" activities since 1990 (Article 3.3) or human-induced activities (Article 3.4). [2.3.2.5]

3.1 Forests, Afforestation, Reforestation, and Deforestation

13. There are many possible definitions of a "forest" and approaches to the meaning of the terms "afforestation," "reforestation," and "deforestation" (ARD). The choice of definitions will determine how much and which land in Annex I countries are included under the provisions of Article 3.3, lands associated with activities included under Article 3.3 (hereafter "lands under Article 3.3"). The amount of land included will have implications for the changes in carbon stocks accounted for under Article 3.3. [2.2.2, 2.2.3, 3.2, 3.5.2, 3.5.3]

14. Seven definitional scenarios were developed that combine definitions of forest and ARD and reflect a range of approaches that can be taken. The scenarios are not intended to be exhaustive. They can be split into two representative groups. ·hich are discussed in the SPM: (1) scenarios in which only a forest/non-forest conversion (i.e., a land-use ·hange triggers accounting under Article 3.3) (e.g.. IPCC Definitional Scenario), and (2) scenarios in which land-cover change or activities trigger accounting under Article 3.3 (e.g., FAO Definitional Scenario). [2.2.2, 2.2.3, 3.2, 3.5.2, 3.5.3, Table 3-4]

15. Countries have defined forests and other wooded lands, for a number of national and international purposes, in terms of (i) legal, administrative, or cultural requirements; (ii) land use; (iii) canopy cover; or (iv) carbon density (essentially biomass density). Such definitions were not designed with the Kyoto Protocol in mind and, thus, they may not necessarily suffice for the particular needs of Articles 3.3 and 3.4. [2.2.2, 3.2]

16. Forest definitions based on legal, administrative, or cultural considerations have limitations for carbon accounting as they may bear little relationship to the amount of carbon at a site. [2.2.2, 3.2]

17. Most definitions of forest are based in part on a single threshold of minimum canopy cover. However, such definitions may allow changes in carbon stocks to remain unaccounted under Article 3.3. For example, if a high threshold for canopy cover (e.g., 70% canopy cover) is used in the definition of a forest, then many areas of sparse forest and woodland could be cleared or could increase in cover without the losses or gains in carbon being counted under Article 3.3. If a low threshold is set (e.g., 10% canopy cover), then dense forest could be heavily degraded and significant amounts of carbon released, without the actions being designated as deforestation. Similarly, a forest, for example with 15% canopy cover, could be considerably enhanced without the actions qualifying as reforestation or afforestation under Article 3.3. Approaches to address partly these problems may include, *inter alia*, using national, regional, or biome-specific thresholds (e.g., a low canopy cover for savannas and a high canopy cover for moist forests). [2.2.2, 3.2, 3.3.2]

18. Definitions of forests based on carbon-density thresholds have similar issues with respect to thresholds as canopy cover-based definitions. [2.2.2]

19. There are a number of approaches to definitions of afforestation, reforestation, and deforestation. One approach involves

the concept of land-use change. Deforestation can be defined as the conversion of forest land to non-forest land. Reforestation and afforestation can be defined as the conversion of non-forested lands to forests with the only difference being the length of time during which the land was without forest. [2.2.3, 3.2]

20. An alternative definition of deforestation might be based on a decrease in the canopy cover or carbon density by a given amount or crossing one of a sequence of thresholds. Similarly, afforestation and reforestation could be defined in terms of an increase in canopy cover or carbon density. None of these definitions involves the concept of a land-use change. [2.2.2, 3.2]

21. Definitions of a forest based strictly on actual canopy cover without consideration of potential canopy cover could lead to harvesting and shifting agriculture being referred to as deforestation and to regeneration being referred to as reforestation, thus creating additional areas of lands under Article 3.3. If the definition of a forest was based on the potential canopy cover at maturity under planned land-use practices, harvesting/regeneration activities may not fall under Article 3.3. [2.2.2, 2.2.3, 3.2]

22. Some commonly used definitions of reforestation include the activity of regenerating trees immediately after disturbance or harvesting where no land-use change occurs. If, for example, the definition of deforestation or the accounting system do not include disturbance and harvesting, then emissions from a harvested stand will not be accounted for. In this particular example, uptake due to regeneration would be accounted for, resulting in potentially significant credits for which a corresponding net removal of carbon from the atmosphere would not occur. This issue could be considered when developing the accounting system. [2.2.3.2]

23. There are several consequences of using definitions that lead to the creation of lands under Article 3.3 by the harvest-regeneration cycle (i.e., where harvesting is included in the definition of deforestation, or regeneration is included in the definition of reforestation). For example, a forest estate managed on a sustainable-yield basis where an area of forest is cut in a regular cycle (e.g., 1/50th of the forest is harvested and regenerated each year on a 50-year rotation cycle) may be in approximate carbon balance. However, in this case, only those stands harvested or regenerated since 1990 would be considered lands under Article 3.3. The regrowth (carbon sink) on these lands will be less than the carbon emissions due to harvesting until all stands of the estate are lands under Article 3.3. Different definitional and accounting approaches would have different accounting consequences. For example:

    - If emissions from harvesting during a commitment period are counted (land-based approach I; see Table 3), then during the first and subsequent commitment periods a net debit could arise from a managed forest estate that is approximately in carbon balance;
    - If emissions from harvesting during a commitment period prior to regeneration are not counted (land-based approach II; see Table 3), then during the first and subsequent commitment periods a net credit would generally arise from a managed forest estate that is approximately in carbon balance. This may be offset to some extent by delayed emissions from soils and harvest residues;
    - If emissions from harvesting during a commitment period are not counted (activity-based approach; see Table 3), then during the first and subsequent commitment periods a net credit would arise from regeneration in a managed forest estate that is approximately in carbon balance. It would be practically very difficult to separate changes in soil carbon pools associated with harvesting and regeneration activities.

    In each of these approaches the accounted stock changes would generally be different from the actual net exchange of carbon between this example forest estate and the atmosphere during a commitment period. [3.2, 3.5.2]

24. Afforestation is usually defined as the establishment of forest on land that has been without forest for a period of time (e.g., 20–50 years or more) and was previously under a different land use. The precise period that distinguishes afforested from reforested land is not important in accounting for lands covered under Article 3.3 provided afforestation and reforestation are treated identically under the Protocol, as they are in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories.[2] [2.2.3, 3.3.2]

25. Article 3.3 encompasses ARD activities that have occurred since 1990 but recognizes only verifiable carbon stock changes in each commitment period. This has several implications. For example:

    - For lands deforested between 1990 and the beginning of the first commitment period only a fraction of carbon stock changes (such as those from delayed carbon emissions from soil and wood products if they are accounted) will occur during the commitment period and would be debited under Article 3.3. If these

2. The Glossary of the Revised 1996 IPCC Guidelines describes afforestation as "Planting of new forests on lands which, historically, have not contained forests. These newly created forests are included in the category Changes in Forest and Other Woody Biomass Stocks in the Land Use Change and Forestry module of the emissions inventory calculations" and reforestation as "Planting of forests on lands which have, historically, previously contained forests but which have been converted to some other use. Replanted forests are included in the category Changes in Forest and Other Woody Biomass Stocks in the Land Use Change and Forestry module of the emissions inventory calculations." Deforestation does not appear in the Glossary of the Revised 1996 IPCC Guidelines. The Revised 1996 IPCC Guidelines state, referring to land-use change, that "Conversion of forests is also referred to as 'deforestation' and it is frequently accompanied by burning." The Revised 1996 IPCC Guidelines were developed before the Kyoto Protocol was adopted and therefore provisions may not be sufficient to meet the needs of the Kyoto Protocol.

***Table 3**: Estimate of accounted average annual carbon stock change for ARD activities. The IPCC and FAO Definitional Scenarios and three accounting approaches under the FAO Definitional Scenario have been applied to illustrate with the available data the effect of different accounting approaches. Other Definitional Scenarios described in Chapter 3, Table 3-4, have not been included in this analysis. The figures and ranges of values in the table are illustrative, provide first-order estimates, and may not encompass the full range of uncertainties. Negative numbers indicate carbon emissions and positive numbers carbon removals. For details, see Table 3-17 in Chapter 3.*

			Area Change (Mha yr^{-1})		Estimated Range of Accounted Average Annual Stock Change 2008–2012 (Mt C yr^{-1}) *Includes carbon in aboveground and below-ground biomass, excludes carbon in soils and in dead organic matter*			
Region	**Activity**	**AR Average Rate of Uptake (t C ha^{-1} yr^{-1}); D Average Stock (t C ha^{-1})**	Post-Harvest Regeneration	Conversion between Non-Forest and Forest	FAO Definitional Scenario, Land-Based I Accounting	FAO Definitional Scenario, Land-Based II Accounting	FAO Definitional Scenario, Activity-Based Accounting	IPCC Definitional Scenario
Boreal Region Total (= Annex I)	AR	0.4 to 1.2	3.1	0.1	–209 to –162	–56 to –8	5 to 48	0 to 2
	D	35		0.5	–18	–18	–18	–18
	Total ARD				–227 to –180	–74 to –26	–13 to 30	–18 to –16
Temperate Region Annex I	AR	1.5 to 4.5	5.4	0.5	-550 to -81	-134 to 303	81 to 519	7 to 44
	D	60		1.2	-72	-72	-72	-72
	Total ARD				-622 to -153	-206 to 231	9 to 447	-65 to -28
Annex I Total	AR		8.5	0.6	-759 to -243	-190 to 295	87 to 573	7 to 46
	D			1.7	–90	–90	–90	–90
	Total ARD				–849 to –333	–280 to 205	–3 to 483	–83 to –44
Temperate Region Total	AR	1.5 to 4.5	n/a	1.9	n/a	n/a	n/a	27 to 167
	D	60		2.1	–126	–126	–126	–126
	Total ARD				n/a	n/a	n/a	–99 to 41
Tropical Region Total	AR	4 to 8	n/a	2.6	n/a	n/a	n/a	170 to 415
	D	120		13.7	–1644	–1644	–1644	–1644
	Total ARD				n/a	n/a	n/a	–1474 to –1229
Global Total (summing regional totals)	AR		n/a	4.6	n/a	n/a	n/a	197 to 584
	D			16.3	–1788	–788	–1788	–1788
	Total ARD				n/a	n/a	n/a	–1591 to –1204

Notes: n/a = no number is provided because the area of regeneration after harvest in the tropical region and part of the temperate region was not available. In addition, regeneration after selective cutting, as it is often used in the tropics, is difficult to capture with the FAO Definitional Scenario. It is assumed that recent area conversion rates ["recent" = for Annex I Parties AR late 1980s/early 1990s and for D 1980s (except for Canada and Russian Federation early 1990s); ARD in other regions 1980s] have applied since 1990, and will continue to do so until 2012. The IPCC Definitional Scenario includes transitions between forest and non-forest land uses under Article 3.3. For the purposes of this table, it is assumed that not only planting, but also other forms of stand establishment such as natural establishment, are considered AR activities. The FAO Definitional Scenario includes the harvest/regeneration cycle, because regeneration is defined as reforestation. Within the FAO Definitional Scenario, three accounting approaches are distinguished (see paragraph 25 and Section 3.3.2). Uptake rates are intended to span the range within which the average value for each region is expected to be. The lower bound of the estimated average annual stock change corresponds to the lower uptake rate in AR and the higher bound to the higher uptake rate. Trees have been assumed to grow according to a sigmoidal growth curve. Estimated area for conversion between non-forest and forest should be regarded as an upper limit for the temperate region total and the tropical region, because some countries may have reported plantations for 1990 but not for 1980, and because some of the plantations may not qualify as resulting from AR activities under the IPCC Definitional Scenario. Also, for tropical countries, the deforestation estimates are very uncertain and could be in error by as much as ±50%.

lands are subsequently reforested then there may be an increase in carbon stocks during the commitment period and a credit under Article 3.3. This would mean that the credit received would not match the actual carbon stock changes or the net exchanges of carbon with the atmosphere since 1990;

- Another accounting issue could arise when land is reforested or afforested between 1990 and 2008 but stocks are reduced either by harvesting or natural disturbance during a commitment period. Even though the forest area and possibly carbon stocks may have increased since 1990, a debit could be recorded in a commitment period. This creates the possibility of a negative incentive for establishing forests well in advance of the first commitment period, because any stock increase prior to 2008 would not be credited but the later loss of this stock would be debited.

Such outcomes could possibly be addressed through different combinations of definitional and accounting approaches. [3.3.2]

26. There are definitional and carbon accounting issues concerning drawing a clear boundary between natural phenomena and human-induced activities, when, for example, significant forest losses occur as a result of fires or disturbances such as pest outbreaks. In cases involving lands under Article 3.3 or 3.4 where fires or pest outbreaks occur in a forest, a question is whether accounting should, *inter alia*: (i) count neither the loss nor subsequent uptake of carbon (which reflects the actual net change in carbon stocks on those lands and exchange of carbon with the atmosphere in the long term, but creates problems in continuing to account for the area burnt/defoliated as lands under Article 3.3 or 3.4); (ii) count both the loss and subsequent uptake of carbon (which reflects the actual net change in carbon stocks on those lands and exchange of carbon with the atmosphere, but creates an initial carbon debit for the Party concerned); (iii) count only the loss of carbon (which would overestimate the actual losses of carbon stocks, not represent the exchanges of carbon with the atmosphere, and create future accounting problems); or (iv) count only the subsequent uptake (which would fail to reflect the actual changes in carbon stock and would not represent the exchanges of carbon with the atmosphere, and would provide carbon credits for the Party concerned). [2.2.3.3]

27. In cases involving lands that do not fall under Articles 3.3 or 3.4, where fires or pest outbreaks trigger land-use change, the consequences are similar to deforestation. If similar vegetation cover is allowed to regenerate, such disturbances may not lead to a long-term change in carbon stocks. [2.4.4, 2.2.3, 2.3.3]

3.2 *Additional Activities*[3]

28. When the inclusion of additional activities under Article 3.4 is considered, it is possible to interpret "activity" broadly (e.g., cropland management) or narrowly (e.g., change in tillage method, fertilization, or cover crops). Under either interpretation, it is, in principle, possible to choose either a land-based or an activity-based method of carbon accounting or a combination of both (see Section 4). These combined choices will affect the accuracy, feasibility, cost, transparency, and verifiability of monitoring and reporting of emissions and removals, including non-CO_2 greenhouse gases, and attributing them to specific activities. [2.3.2.2, 4.3.1, 4.3.2]

29. The term "broad activity" means an activity definition that is land- or area-based, where the net effect of all practices applied within the same area are included. A broad activity definition is likely to require land-based accounting (see paragraph 34). This definitional approach would capture the net emission or removal effects of practices that deplete carbon stocks as well as those that increase removals by sinks. Broad activity definitions, particularly in cases where land-use change is involved, may make it difficult to separate human-induced changes from naturally-induced changes. [2.3.2, 4.3.2]

30. The narrow definition of "activity" is based on individual practices, such as reduced tillage or irrigation water management. The narrow definition may lend itself to activity-based accounting, but land-based accounting is also possible. Under activity-based accounting, discrete definitions and associated rates of emissions or removals are needed for each individual practice. Narrow definitions raise the potential for multiple activities to occur on a single land area, raising accounting issues (see paragraph 33). Narrow activity definitions may facilitate the separation of human-induced changes from natural influences (see paragraph 45). [4.2.1, 4.3.2, 4.3.4]

4. Carbon Accounting

31. A well-designed carbon accounting system would provide transparent, consistent, comparable, complete, accurate, verifiable, and efficient recording and reporting of changes in carbon stocks and/or changes in greenhouse gas emissions by sources and removals by sinks from applicable land use, land-use change, and forestry activities and projects under relevant Articles of the Kyoto Protocol. Such data would be needed to assess compliance with the commitments under the Kyoto Protocol. Two possible accounting approaches towards meeting these requirements are outlined below, of which either one — or combination of the two — could be adopted (see Figure 1). [2.3.1]

32. A "land-based" approach to accounting would take as its starting point the change in carbon stock in applicable carbon pools on lands containing activities included under

[3] The technical issues addressed in paragraph 26 also apply to additional activities adopted under Article 3.4, but are not repeated here for conciseness.

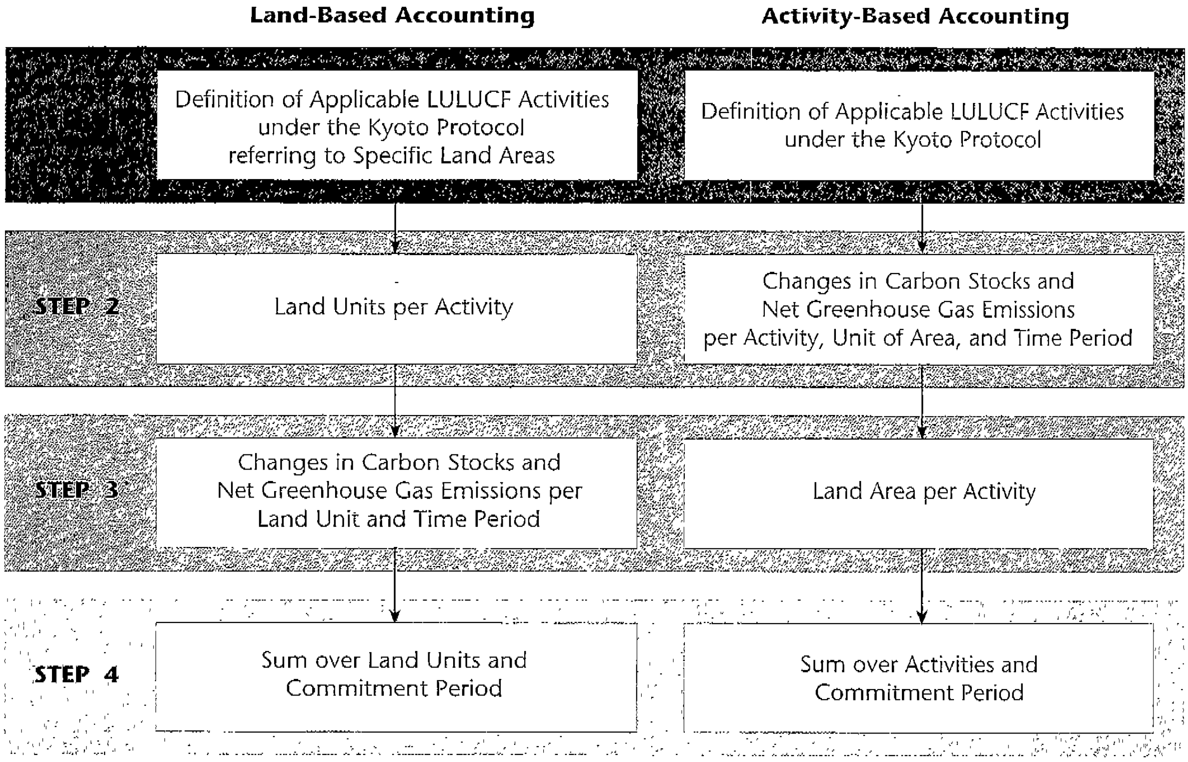

Figure 1: Accounting approaches.

Article 3.3 or accepted under Article 3.4. This involves first defining the applicable activities, and in the next step identifying the land units on which these activities occur. Next, the change in carbon stocks on these land units during the relevant period is determined. In the land-based approach, it could be difficult to factor out the impact on stocks of indirect effects (see paragraph 44). Non-CO_2 greenhouse gas emission estimates would also need to be accounted for. Modifications could be made regarding, for example, baselines, leakage, timing issues, permanence, and uncertainties. Aggregate accounted CO_2 emissions and removals are the sum of carbon stock changes (net of any modifications) over all applicable land units over the specified time period. [2.3.2, 3.3.2]

33. An "activity-based" approach to accounting would start with the carbon stock change in applicable carbon pools and/or emissions/removal of greenhouse gases attributable to designated LULUCF activities. After defining the applicable activities, each applicable activity's impact on carbon stocks is determined per unit area and time unit. This impact is multiplied by the area on which each activity occurs and by the years it is applied or the years of the commitment period. Modifications could be made regarding, for example, baselines, leakage, timing issues, permanence, and uncertainties. Aggregate accounted emissions and removals are calculated by summing across applicable activities. Potentially a given area of land could be counted more than once if it is subject to multiple activities. If the effects of activities are not additive, this would result in inaccurate accounting. In this case, the carbon stock would be especially difficult to verify. Alternatively, the Parties could decide that each land unit could contain no more than a single activity. In this case, the combined impact of multiple practices applied in the same area would be considered a single activity. [2.3.2, 3.3.2, 4.3.3]

34. The land-based approach to accounting could start either with the start of the activity or run for the entire commitment period, while the activity-based approach would start when the activity starts or at the beginning of the commitment period, whichever is later. Either accounting approach could end according to decisions that the Parties might adopt. In the activity-based approach, stock changes prior to the start of the activity would not be accounted, even if they occur in a commitment period. [2.3.2]

35. Some activities must be persistently maintained to retain the stored carbon stocks, and this may influence the accounting methods required. Conservation tillage, for example, may increase carbon stocks on cropland if carried on continuously, but where it is practiced for a time, then interrupted by a year of intensive tillage brought on by, for example, a weather situation or crop change, much of the previous multi-year gain in soil carbon can be lost. Land-based estimates of the cropland estate should reflect the net effect of

those gains and losses over the full area during the accounting period and give verifiable results, provided statistically representative sampling procedures are in place. If activity-based accounting occurs without sampling, it may report results inconsistent with actual stock changes during the accounting period. [2.3.2]

36. For technical reasons, only emissions and removals of CO_2 can be determined directly as changes in carbon stocks. Methane emissions and removals cannot in practice be directly measured as carbon stock changes, although CH_4 and N2O can be determined by other means. Methane and nitrous oxide emissions from many land-use activities are included in Annex A of the Kyoto Protocol (e.g., rice cultivation, enteric fermentation, and agricultural soils) and in the Revised 1996 IPCC Reporting Guidelines for National Greenhouse Gas Inventories, and therefore they will be captured in national inventories. This is not the case, however, for emissions of these gases related to forestry activities and projects, which are not included in Annex A, although some of these forestry activities are discussed in the 1996 Revised IPCC Guidelines for National Greenhouse Gas Inventories. If the net emissions of CH_4 and N_2O are not considered, the full climate impact of forestry activities may not be reflected in the accounting system under the Kyoto Protocol. The treatment of CH_4 and N_2O emissions under Article 3.3 may deserve further consideration and clarification. For agreed activities, Article 3.4 leaves open how net greenhouse gas emissions will be accounted for in meeting the commitments under Article 3.1 of the Protocol. [2.3.2, 3.3.2]

37. Relevant carbon pools could include aboveground biomass, litter and woody debris, below-ground biomass, soil carbon, and harvested materials. The impact on these different carbon pools may vary significantly between activities and types of projects. While methods exist to measure all carbon pools, to date monitoring is not routinely performed on all pools and the costs vary significantly. A conservative approach that would allow for selective accounting of carbon pools to reduce monitoring costs could be to include all those pools anticipated to have reduced carbon stocks while omitting selected pools anticipated, with a sufficient level of certainty, to have unchanged or increased carbon stocks. Similar approaches could be used for fluxes of non-CO_2 greenhouse gases. Under this approach, verifiability would mean that only increases in carbon stocks and removal by sinks that can be monitored and estimated could potentially be credited. [2.3.7, 3.3.2, 4.2.1]

38. Accounting for LULUCF activities under Articles 3.3 and 3.4 includes different types of uncertainties, including measurement uncertainty, uncertainty in identifying lands under Article 3.3 or 3.4, and uncertainty in defining and quantifying baselines, if any. This uncertainty can be accounted for in several ways. One approach is to extend the application of good practice guidance in the choice of methods and handling of uncertainty in estimates which has been developed by the IPCC for other inventory categories. Another approach could be to adjust estimated stock changes in a conservative way — understating increases and overstating decreases in stocks. The latter option could allow tradeoffs between monitoring costs and the potential to receive increased carbon credits or reduced debits, but would not be consistent with established principles for estimation of emissions and removals in greenhouse gas inventories. [2.3.7]

39. Changes in carbon stocks in wood products could potentially be accounted as part of the activity that is the source of the wood products or as an independent wood products management activity. If management of wood products is treated as an additional activity under Article 3.4, then it may be necessary to exclude wood products from accounting under other Article 3.3 or 3.4 activities to avoid double-counting. Once wood products are in trade, they would be difficult in most instances to trace. The current IPCC default approach assumes that the wood product pool remains constant over time, and therefore does not account for it. However, if this pool is changing significantly over time, a potentially important pool may not be accounted for. [2.4.2, 3.3.2, 4.5.6, 6.3.3]

40. Enhancement of carbon stocks resulting from land use, land-use change, and forestry activities is potentially reversible through human activities, disturbances, or environmental change, including climate change. This potential reversibility is a characteristic feature of LULUCF activities in contrast to activities in other sectors. This potential reversibility and nonpermanence of stocks may require attention with respect to accounting, for example, by ensuring that any credit for enhanced carbon stocks is balanced by accounting for any subsequent reductions in those carbon stocks, regardless of the cause. [2.3.6, 3.3.2]

41. Contiguous commitment periods under the Kyoto Protocol would avoid incentives in subsequent periods to concentrate activities that reduce carbon stocks in time periods that were not covered. [2.3.2]

42. Policies by governments or other institutions (e.g., land tenure reform and tax incentives) may provide a framework and incentives for implementing LULUCF activities. Changes in markets may also affect the economic conditions for land use, land-use change, and forestry activities. The ability to measure the impact of these conditions and incentives will depend, in part, upon the carbon inventory and monitoring system in each country. However, it may be very difficult for countries to assess the relative impact of policies by governments or other institutions compared to other human and natural factors that drive changes in carbon stocks. [2.3.5, 5.2.2]

43. Natural variability, such as *El Niño* cycles, and the indirect effects of human activity, such as CO_2 fertilization, nutrient deposition, and the effects of climate change, could significantly affect carbon stocks during a commitment period on lands under Article 3.3 or 3.4. The spatial distribution of

the emissions and removals of greenhouse gases due to these factors is uncertain, as is the portion of them that may enter the accounting system. These emissions and removals could be potentially large compared to the commitments in the first commitment period. This could be a significant issue in the design of an accounting framework. [2.3.3]

44. The Kyoto Protocol specifies that accounting under Article 3.3 be restricted to "direct human-induced land-use change and forestry activities, limited to afforestation, reforestation, and deforestation" occurring since 1990. For activities that involve land-use changes (e.g., from grassland/ pasture to forest) it may be very difficult, if not impossible, to distinguish with present scientific tools that portion of the observed stock change that is directly human-induced from that portion that is caused by indirect and natural factors. [2.3.4, 3.3.2]

45. For those activities where only narrowly defined management changes under Article 3.4 are involved (e.g., conservation tillage) and the land use remains the same, it may be feasible to factor out partially natural variability and indirect effects. One approach may be to subtract the stock changes on comparison plots where there have been no changes in management practice from changes measured on plots with modified management activities. In most cases, experimental manipulation or paired plots can be used for this purpose, but they are likely to be expensive to apply over large areas. Ecosystem models can also be used but need further improvement to decrease uncertainties. Verifiability could be assisted by the application of a combination of models and measurements. [2.3.4, 4.3.4]

46. Baselines could be used in some cases to distinguish between the effects of LULUCF activities and other factors, such as natural variability and the indirect effects of human activities, as well as to factor out the effects of business-as-usual and activities undertaken prior to 1990 on carbon stock accounts and net greenhouse gas emissions. If the concept of a baseline was to be applied in national accounting for activities under Article 3.4, there are many options, which include: (i) the stock/flux change that would have resulted from "business-as-usual" activities; (ii) the stock/flux change that would have resulted from the continuation of 1990 activity levels; (iii) the stock/flux change that would result in the absence of active management; (iv) performance benchmarks or standard management practice; and (v) the rate of change of stocks/fluxes in 1990. The first three of these baseline options may involve the use of a counterfactual scenario. One difficulty with the use of counterfactual baselines is verification. [2.3.4, 4.6, 4.6.3.3]

47. Accounting under the terms land-use change and forestry in Article 3.7 will determine which emissions and removals of carbon will enter the 1990 base year or period for some countries. If the land-use change activities giving rise to these emissions and removals are not included under Article 3.3 or 3.4 during the commitment periods, then the inventories of countries subject to this clause in Article 3.7 would not be calculated on the same basis as their 1990 emissions base year or period. [3.3.2]

48. If different accounting rules are adopted for relevant Articles of the Kyoto Protocol, additional decision rules may be needed to determine which accounting rule applies to land that, over time, is subject to multiple types of activities. For example, one set of accounting rules could be given primacy in cases where more than one set could potentially apply and double-counting might result. [2.3.2, 3.3.2]

49. Leakage is changes in emissions and removals of greenhouse gases outside the accounting system that result from activities that cause changes within the boundary of the accounting system. There are four types of leakage: activity displacement, demand displacement, supply displacement, and investment crowding. If leakage occurs, then the accounting system will fail to give a complete assessment of the true aggregate changes induced by the activity. Although leakage is in many cases a negative effect, situations, such as the demonstration effect of new management approaches or technology adoption, may occur where the emissions reductions or removals of greenhouse gases extend beyond the accounting system boundaries (positive spillover effect). For some activities and project types, leakage may be addressed by increasing the spatial and temporal scale of the accounting system boundaries (i.e., by including areas where changes in removal and emissions of greenhouse gases may be induced). However, leakage may extend beyond any activity accounting boundaries (e.g., beyond national boundaries). Leakage is of particular concern in project-level accounting, but may also occur with activities under Articles 3.3 and 3.4. [2.3.5.2, 5.3.3]

Part III

5. Methods for Measuring and Monitoring

50. Lands under Articles 3.3 and 3.4 could be identified, monitored, and reported using geographical and statistical information. Changes in carbon stocks and net greenhouse gas emissions over time can be estimated using some combination of direct measurements, activity data, and models based on accepted principles of statistical analysis, forest inventory, remote-sensing techniques, flux measurements, soil sampling, and ecological surveys. These methods vary in accuracy, precision, verifiability, cost, and scale of application. The cost of measuring changes in carbon stocks and net greenhouse gas emissions for a given area increases as both desired precision and landscape heterogeneity increase. [2.4, 3.4]

51. The spatial resolution of monitoring has important implications for accuracy and costs. If a small minimum

resolvable land area is used, the task and cost of monitoring can become very demanding. If the spatial resolution is set at a coarse scale, the data demands can be modest, but significant areas subject to an activity may be lost in the averaging process. For example, if forests and deforestation are defined in terms of canopy cover and canopy cover is assessed over land areas of 100 ha, then deforestation of smaller areas within a unit may not take the canopy cover of the unit below the forest definition threshold. Thus, changes in carbon stocks may not be accounted and, likewise, afforestation or reforestation of small areas may not be accounted. Hence, there are clear tradeoffs between an accurate and precise assessment of changes in carbon stocks and cost. However, an appropriate design should result in a statistically reliable estimate. [2.2.2]

52. The technical capacity required by Annex I Parties to measure, monitor, and verify carbon stock changes and net greenhouse gas emissions under the Kyoto Protocol will be significantly affected by decisions of the Parties regarding definitions of key terms related to land use, land-use change, and forestry activities. It will also depend on decisions on, inter alia, additional activities that may be included under Article 3.4, and whether additional activities are defined broadly or narrowly. Depending upon decisions that may be made, establishing a monitoring, reporting, and verification system under Articles 3.3 and 3.4 is likely to involve a significant effort by Annex I Parties, given the technology, data, and resources required, and the short time available. [2.4.1, 3.4, 4.3.2, 4.3.5]

53. Annex I Parties generally have the basic technical capacity (soil and forest inventories, land-use surveys, and information based on remote-sensing and other methods) to measure carbon stocks and net greenhouse gas emissions in terrestrial ecosystems. However, few, if any, countries perform all of these measurements routinely, particularly soil inventories. Some Annex I Parties may use existing capacity with minimal modification to implement the various Articles in the Kyoto Protocol; however, some other Annex I Parties may need to improve significantly their existing measurement systems in order to develop operational systems. Non-Annex I Parties may require technical, institutional, and financial assistance and capacity building for measuring, monitoring, and verifying carbon stock changes as well as for estimating net greenhouse gas emissions. [2.4.6, 3.4.3, 4.2]

54. Technical methods for measuring and estimating changes in forest carbon stocks in aboveground biomass over a five-year commitment period may be deemed to be sensitive enough to serve the requirements of the Protocol. Sensitive methods for estimating below-ground carbon stocks also exist. However, changes in soil carbon stocks are in some instances small and difficult to assess accurately over a five-year time period. This problem may be addressed by adopting appropriate sampling techniques supported by modeling that take into account spatial variability. Methods that further improve estimates of soil and vegetation carbon stock will depend on future research and model development and are likely to be highly transferable between Parties. [2.4.2, 2.4.3, 4.2.2, 5.4.1]

6. Estimates of Average Annual Carbon Stock Changes/Accounted for ARD Activities and Some Additional Activities

6.1 Afforestation, Reforestation, and Deforestation

55. Different definitions and accounting approaches under Article 3.3 of the Kyoto Protocol produce different estimates of changes in carbon stocks. There are seven Definitional Scenarios described in Chapter 3 of the underlying report. Table 3 illustrates, with data and methods available at the time of the Special Report, the estimated carbon stock changes accounted from ARD activities under the IPCC and FAO Definitional Scenarios, assuming recent area conversion rates remain constant and excluding carbon in soils and wood products. Three different carbon accounting approaches have been applied to the FAO Definitional Scenario to illustrate the effect of different accounting approaches. [3.5.3, 3.5.4, Table 3-4, Table 3-17]

56. The IPCC Definitional Scenario yields estimates of average annual accounted carbon stock changes from afforestation and reforestation in Annex I Parties from 2008 to 2012 of 7 to 46 Mt C yr^{-1}. This would be offset by annual changes in carbon stocks from deforestation of about –90 Mt C yr^{-1}, producing a net stock change of -83 to –44 Mt C yr^{-1}. If hypothetically, for example, afforestation and reforestation rates were to be increased in Annex I Parties by 20%[4] for the years 2000 to 2012, estimated annual changes in carbon stocks would increase (from 7 to 46 Mt Cyr^{-1}) to 7 to 49 Mt C yr^{-1}. If hypothetically, for example, deforestation rates were to be decreased by 20%, estimated annual losses of carbon stocks due to deforestation would reduce (from –90 Mt C yr^{-1}) to –72 Mt C yr^{-1}. [3.5.4]

57. The three accounting approaches under the FAO Definitional Scenario yield different results. Estimated average annual carbon stock changes in Annex I Parties from afforestation and reforestation are –759 to –243 Mt C yr^{-1} under the FAO land-based I approach; –190 to 295 Mt C yr^{-1} under the FAO land-based II approach; and 87 to 573 Mt C yr^{-1} under the FAO activity-based approach. Estimated average annual carbon stock changes from deforestation are about –90 Mt C yr^{-1} in all three approaches, as in the IPCC Definitional Scenario. [3.5.4]

58. For comparison, the IPCC Definitional Scenario yields estimates of average annual accounted carbon stock changes from afforestation and reforestation globally from 2008 to 2012 of 197 to 584 Mt C yr^{-1}. This would be offset

4. The 20% is an arbitrary value chosen to show the sensitivity of the estimates to changes in practices.

by annual changes in carbon stocks from deforestation of about –1 788 Mt C yr^{-1}, producing a net stock change of –1 591 to –1 204 Mt C yr^{-1}. If, hypothetically, for example, afforestation and reforestation rates were to be increased globally by 20% for the years 2000 to 2012, estimated annual changes in carbon stocks would increase (from 197 to 584 Mt C yr^{-1}) to 208 to 629 Mt C yr^{-1}. [3.5.4]

59. In the IPCC Definitional Scenario and FAO Definitional Scenario with land-based I accounting approach, the accounted carbon stock changes are broadly consistent with the 2008–2012 actual changes in carbon stocks from land under Article 3.3. The IPCC and FAO Definitional Scenarios bring different amounts of land under Article 3.3, hence the estimated carbon stock changes in Table 3 differ.

60. In the FAO Definitional Scenario with land-based II and activity-based accounting approaches, the accounted carbon stock change is not consistent with the 2008–2012 actual changes in carbon stocks on land under Article 3.3, except in the case of short rotation cycles.

61. In neither of the two Definitional Scenarios is the accounted carbon stock change consistent with the 2008–2012 actual carbon stock changes, nor with the net exchanges with the atmosphere, at the national and global levels in part because the land under Article 3.3 is small in comparison with the national and global forest area. [3.3.2, 3.5.4]

6.2 Additional Activities

62. The magnitude of the stock changes from additional activities that might be included under Article 3.4 rests, inter alia, on any decisions that remain to be made in the process of implementing the Kyoto Protocol. A consideration of carbon stocks changes and net emissions of greenhouse gas emissions associated with additional activities on managed lands entails synthesizing available technical and scientific data, outlining the outcomes of one policy scenario, and assessing the aggregate impact of policies and other factors. The scientific literature to support such an analysis is currently quite limited. [4.3]

63. One such scenario is presented in Table 4, to illustrate in a general sense the potential scope for carbon stock increases through some broadly defined activities. It provides data and information on carbon stock changes for some candidate activities under Article 3.4 for the year 2010. This scenario relies on three components relating to the candidate activities: (1) an estimate of current relevant land areas (column 2); (2) an assumed percentage of those lands on which an activity would be applied in 2010 (column 3); and (3) a research-derived estimate of the annual rate of carbon stock increase per hectare (column 4). The uptake rate is multiplied by the applicable land area to approximately calculate the change in carbon stock in the year 2010 (column 5).

64. Table 4, rather than providing precise projections, reports calculated stock changes assuming an ambitious policy agenda that promotes the application of activities to a significantly greater share of the relevant land base than would have otherwise occurred. The assumed percentage of lands on which the activity is applied is derived from considered professional judgment based on existing literature of what a range of sustained and effective initiatives, which vary across countries, could achieve. The share of land on which the activity is actually applied in 2010 depends to a great extent on the accounting system under Article 3.4, the evolving economic and social aspects of the activity, and landowner response to incentives, among other factors. Thus, the total annual stock changes in Table 4 (column 5) are likely to be on the high side.

65. Table 4 estimates do not necessarily represent credits under Article 3.4 of the Kyoto Protocol, even if such levels of stock change are achieved, because the Protocol may include approaches that limit the applicability of these calculations.

66. Table 4 illustrates the estimated carbon stock changes from example additional activities within Annex I and globally, assuming roughly similar levels of policy support. For example, Table 4 suggests that although conversion of cropland to grassland can provide a relatively large carbon stock increase per hectare converted, forest management improvements, which can be applied over a larger land base, may provide relatively larger total annual increases. Very different estimates in changes of emissions and removals associated with options for additional land use, land-use change, and forestry activities would result from different definitions of additional activities that might be agreed under Article 3.4, different accounting approaches, and different decisions that might be taken on implementation rules for Article 3.4.

67. There is potential for carbon uptake into biomass, which may be stored over a time period of decades in wood products. Furthermore, biomass used for energy purposes, based on waste by-products of wood/crops or from trees/crops grown expressly for this purpose, has the potential to lead to a reduction in net greenhouse gas emissions by substituting for fossil fuels. [1.4.3, 1.4.4]

68. Table 4 does not account for the possibly significant non-CO_2 greenhouse gas emissions and removals that could be influenced by the candidate activities. For example, the rates do not reflect net emissions of CH_4 or N_2O from agricultural practices or wetlands/permafrost management. The table also does not include the carbon stock impact of the use of biofuels and the changing wood product pools, and consideration of forest management does not include avoided deforestation, which is dealt with in Table 3.

7. Project-Based Activities

69. A LULUCF project can be defined as a planned set of activities aimed at reducing greenhouse gas emissions or

Table 4: Relative potential in 2010 for net change in carbon stocks through some improved management and changed land-use activities.[a]

(1) Activity	(2) Total Area[b] (Mha)	(3) Assumed Percentage of Total Area of Column 2 under Activity in 2010 (%)	(4) Net Annual Rate of Change in Carbon Stocks per Hectare[b] (t C ha^{-1} yr^{-1})	(5) Estimated Net Change in Carbon Stocks in 2010 (Mt C yr^{-1})
A. Annex I Countries				
(a) Improved Management within a Land Use[c]				
Forest Management	1 900	10	0.5	100
Cropland Management	600	40	0.3	75
Grazing Land Management	1 300	10	0.5	70
Agroforestry	83	30	0.5	12
Rice Paddies	4	80	0.1	<1
Urban Land Management	50	5	0.3	1
(b) Land-Use Change				
Conversion of Cropland to Grassland	600	5	0.8	24
Agroforestry	<1	0	0	0
Wetland Restoration	230	5	0.4	4
Restoring Severely Degraded Land	12	5	0.25	1
B. Global Estimates				
(a) Improved Management within a Land Use				
Forest Management	4 050	10	0.4	170
Cropland Management	1 300	30	0.3	125
Grazing Land Management	3 400	10	0.7	240
Agroforestry	400	20	0.3	26
Rice Paddies	150	50	0.1	7
Urban Land Management	100	5	0.3	2
(b) Land-Use Change				
Agroforestry	630	20	3.1	390
Conversion of Cropland to Grassland	1 500	3	0.8	38
Wetland Restoration	230	5	0.4	4
Restoring Severely Degraded Land	280	5	0.3	3

[a] Totals were not included in the table for several reasons: (i) The list of candidate activities is not exclusive or complete; (ii) it is unlikely that all countries would apply all candidate activities; and (iii) the analysis does not presume to reflect the final interpretations of Article 3.4. Some of these estimates reflect considerable uncertainty.

[b] A summary of reference sources is contained in Tables 4-1 and 4-4 of this Special Report. Calculated values were rounded to avoid the appearance of precision beyond the intent of the authors. The rates given are average rates that are assumed to remain constant to 2010.

[c] Assumed to be the best available suite of management practices for each land use and climatic zone.

enhancing carbon stocks that is confined to one or more geographic locations in the same country and specified time period and institutional frameworks such as to allow net greenhouse gas emissions or enhancing carbon stocks to be monitored and verified. Experience is being gained in Activities Implemented Jointly (AIJ) and other LULUCF projects that are under initial stages of implementation in at least 19 countries.

70. Assessment of the experience of these projects is constrained by the small number, the limited range of project types, the uneven geographic distribution, the short period of field operations to date, and the absence of an internationally agreed set of guidelines and methods to establish baselines and quantify emissions and uptake. Generally, these projects do not report all greenhouse gas emissions or estimate leakage, and few have independent review.

71. However, through the experience of LULUCF projects aimed to mitigate climate change, it is possible in some cases to develop approaches to address some of the critical issues (see Table 5).

72. There are 10 projects aimed at decreasing emissions through avoiding deforestation and improving forest management, and 11 projects aimed at increasing the uptake of carbon — mostly forest projects in tropical countries (see Table 5). [5.2.2]

Table 5: *Carbon uptake/estimated emissions avoided from carbon stocks, assuming no leakage outside the project boundaries, by selected AIJ Pilot Phase and other LULUCF projects, in some level of implementation.*[a,b,c,d,e]

Project Type (number of projects)	Land Area (Mha)	Accumulated Carbon Uptake over Project Lifetime (Mt C)	Estimated Carbon Uptake per Spatial Unit during the Project Lifetime ($t\ C\ ha^{-1}$)	Accumulated Estimated Emissions Avoided over the Project Lifetime (Mt C)	Estimated Emissions Avoided from Carbon Stocks per Spatial Unit during the Project Lifetime ($t\ C\ ha^{-1}$)
		assuming no leakage outside the project boundaries			
Forest Protection (7)[f]	2.8			41–48	4–252
Improved Forest Management (3)	0.06			5.3	41–102
Reforestation and Afforestation (7)	0.1	10–10.4	26–328		
Agroforestry (2)	0.2	10.5–10.8	26–56		
Multi-Component and Community Forest (2)	0.35	9.7	0.2–129		

[a] Projects included are those for which we have sufficient data. Soil carbon management, bioenergy, and other projects are not included for this reason.
[b] "Some level of implementation" — Included projects have been partially funded and have begun activities on the ground that will generate increases in carbon stocks and reductions in greenhouse gas emissions.
[c] "Other LULUCF projects" — Refers to selected non-AIJ projects and projects within Annex I countries.
[d] Estimated changes in carbon stocks generally have been reported by project developers, do not use standardized methods, and may not be comparable; only some have been independently reviewed.
[e] Non-CO_2 greenhouse gas emissions have not been reported.
[f] Protecting an existing forest does not necessarily ensure a long-term contribution to the mitigation of the greenhouse effect because of the potential for leakage and reversibility through human activities, disturbances, or environmental change. Table 5 does not provide an assessment in relation to these issues. Sound project design and management, accounting, and monitoring would be required to address these issues.

73. Methods of financial analysis among these projects have not been comparable. Moreover the cost calculations do not cover, in most instances, inter alia, costs for infrastructure, monitoring, data collection and interpretation costs, opportunity costs of land and maintenance, or other recurring costs, which are often excluded or overlooked. Recognizing the different methods used, the undiscounted cost and investment estimates range from US$ 0.1–28 per ton of carbon, simply dividing project cost by their total reported accumulated carbon uptake or estimated emissions avoided, assuming no leakage outside the project boundaries. [5.2.3]

74. Project-level financial analysis methods are widely used and fairly standardized in development assistance and private investment projects. But they have yet to be consistently applied to, and reported for, LULUCF projects aiming at mitigating climate change. Guidelines for developing methods of financial analysis may be needed in the future. [5.2.3]

75. LULUCF projects aiming to mitigate climate change may provide socioeconomic and environmental benefits primarily within project boundaries, although they may also pose risks of negative impacts. Experience from most of the pilot projects to date indicates that involvement of local stakeholders in the design and management of project activities is often critical. Other factors affecting the capacity of projects to increase carbon uptake and avoid greenhouse gas emissions and to have other benefits include consistency with national and/or international sustainable development goals, and institutional and technical capacity to develop and implement project guidelines and safeguards. [2.5.2, 5.6]

76. The accounting of changes in carbon stocks and net greenhouse gas emissions involve a determination that project activities lead to changes in carbon stocks and net greenhouse gas emissions that are additional to a without-project base line. Currently there is no standard method for determining baselines and additionality. Approaches include determining project-specific baselines or generic benchmarks. Most AIJ projects have used a project-specific approach that has an advantage of using better knowledge of local conditions yielding more accurate prediction. A disadvantage is that project developers may choose scenarios that maximize their projected benefits. Baselines may be fixed throughout the duration of a project or periodically adjusted. Baseline adjustments would ensure more realistic estimates of changes in carbon uptake or greenhouse gas emissions but would create uncertainties for project developers. [5.3.2, Table 5-4]

77. Projects that reduce access to land, food, fiber, fuel, and timber resources without offering alternatives may result in carbon leakage as people find needed supplies elsewhere. A few pilot projects have been designed with the aim of reducing leakage by explicitly incorporating components

that supply the resource needs of local communities (e.g., establishing fuelwood plantations to reduce pressures on other forests), and that provide socioeconomic benefits that create incentives to maintain the project. Due to leakage, the overall consideration of the climate change mitigation effects of a project may require assessments beyond the project boundary, as addressed in paragraph 49. [2.3, 5.3.3]

78. Project accounting and monitoring methods could be matched with project conditions to address leakage issues. If leakage is likely to be small, then the monitoring area can be set roughly equal to the project area. Conversely, where leakage is likely to be significant the monitoring area could be expanded beyond the project area, although this would be more difficult when the leakage occurs across national boundaries. Two possible approaches could then be used to estimate leakage. One would be to monitor key indicators of leakage, and the second would be to use standard risk coefficients developed for project type and region. In either case, leakage could be quantified and subsequently changes in carbon stock and greenhouse gas emissions attributed to the project could be reestimated. The effectiveness of these two approaches is untested. [5.3.3]

79. LULUCF projects raise a particular issue with respect to permanence (see paragraph 40). Different approaches have been proposed to address the duration of projects in relation to their ability to increase carbon stocks and decrease greenhouse gas emissions, *inter alia*: (i) They should be maintained in perpetuity because their "reversal" at any point in time could invalidate a project; and (ii) they should be maintained until they counteract the effect of an equivalent amount of greenhouse gases emitted to the atmosphere. [5.3.4]

80. Several approaches could be used to estimate the changes in carbon stocks and greenhouse gas emissions of LULUCF projects: (i) estimating carbon stocks and greenhouse gas emissions at a given point in time; (ii) estimating the average changes of carbon stocks or greenhouse gas emissions over time in a project area; or (iii) allowing for only a part of the total changes in carbon stocks or greenhouse gas emissions for each year that the project is maintained (e.g., tonne-year method). The year-to-year distribution of changes in carbon stocks and greenhouse gas emissions over the project duration varies according to the accounting method used. [5.4.2, Table 5-9]

81. LULUCF projects are subject to a variety of risks because of their exposure to natural and anthropogenic factors. Some of these risks particularly pertain to land-use activities (e.g., fires, extreme meteorological events, and pests for forests), while others are applicable to greenhouse gas mitigation projects in both LULUCF and energy sectors such as political and economic risks. Risk reduction could be addressed through a variety of approaches internal to the project, such as introduction of good practice management systems, diversification of project activities and funding sources, self-insurance reserves, involvement of local stakeholders, external auditing, and verification. External approaches for risk reduction include standard insurance services, regional carbon pools, and portfolio diversification. [5.3.5]

82. Techniques and tools exist to measure carbon stocks in project areas relatively precisely depending on the carbon pool. However, the same level of precision for the climate change mitigation effects of the project may not be achievable because of difficulties in establishing baselines and due to leakage. Currently, there are no guidelines as to the level of precision to which pools should be measured and monitored. Precision and cost of measuring and monitoring are related. Preliminary limited data on measured and monitored relevant aboveground and below-ground carbon pools to precision levels of about 10% of the mean at a cost of about US$ 1–5 per hectare and US$ 0.10–0.50 per ton of carbon have been reported. Qualified independent third-party verification could play an essential role in ensuring unbiased monitoring. [5.4.1, 5.4.4]

8. Reporting Guidelines for the Relevant Articles of the Kyoto Protocol

83. Under Article 5.2 of the Kyoto Protocol, the Revised 1996 Guidelines for National Greenhouse Gas Inventories provide the basis for the accounting and reporting of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol. These Guidelines were developed to estimate and report national greenhouse gas inventories under the United Nations Framework Convention on Climate Change (UNFCCC), not for the particular needs of the Kyoto Protocol. However, the Guidelines do provide a framework for addressing the accounting and reporting needs of the Kyoto Protocol. Elaboration of the Land-Use Change and Forestry Sector of the Guidelines may be needed, reflecting possible decisions by the Parties for accounting and reporting LULUCF under the Kyoto Protocol, taking into account, *inter alia*:

- Any decisions made by Parties on ARD under Article 3.3 and on additional activities under Article 3.4; [6.3.1, 6.3.2]
- The need to ensure transparency, completeness, consistency, comparability, accuracy, and verifiability; [6.2.2, 6.2.3, 6.4.1]
- Consistent treatment of Land-Use Change and Forestry as other Sectors, with respect to uncertainty management and other aspects of good practice; [6.4.1]
- Any decisions adopted by Parties to address other accounting issues (e.g., permanence, the meaning of "human induced" and "direct human induced," wood products, and project based activities). [6.4.1]

9. Potential for Sustainable Development

84. Consideration would need to be given to synergies and tradeoffs related to LULUCF activities under the UNFCCC and its Kyoto Protocol in the context of sustainable development including a broad range of environmental, social, and economic impacts, such as: (i) biodiversity; (ii) the quantity and quality of forests, grazing lands, soils, fisheries, and water resources; (iii) the ability to provide food, fiber, fuel, and shelter; and (iv) employment, human health, poverty, and equity. [2.5.1, 3.6]

85. For example, converting non-forest land to forest will typically increase the diversity of flora and fauna, except in situations where biologically diverse non-forest ecosystems, such as native grasslands, are replaced by forests consisting of single or a few species. Afforestation can also have highly varied impacts on groundwater supplies, river flows, and water quality. [3.6.1]

86. A system of criteria and indicators could be used to assess and compare sustainable development impacts across LULUCF alternatives. While there are no agreed upon set of criteria and indicators, several sets are being developed for closely related purposes, for example assessment of contributions to sustainable development by the United Nations Commission on Sustainable Development. [2.5.2]

87. For activities within countries or projects between countries, if sustainable development criteria vary significantly across countries or regions, there may be incentives to locate activities and projects in areas with less stringent environmental or socioeconomic criteria. [2.5.2]

88. Several sustainable development principles are incorporated in other multilateral environmental agreements, including the United Nations Convention on Biological Diversity, the United Nations Convention to Combat Desertification, and the Ramsar Convention on Wetlands. Consideration may be given to the development of synergies between LULUCF activities and projects that contribute to the mitigation or adaptation to climate change with the goals and the objectives of these and other relevant multilateral environmental agreements. [2.5.2]

89. Some of the more formal approaches to sustainable development assessment that could be applied at the project level are, for example, environmental and socioeconomic impact assessments. These methods have been applied across a wide range of countries and site-specific activities to date and could be modified to be applicable to LULUCF projects. [2.5.2.2]

90. Some critical factors affecting the sustainable development contributions of LULUCF activities and projects to mitigate and adapt to climate change include: institutional and technical capacity to develop and implement guidelines and procedures; extent and effectiveness of local community participation in development, implementation, and distribution of benefits; and transfer and adoption of technology. [5.5, 5.6]

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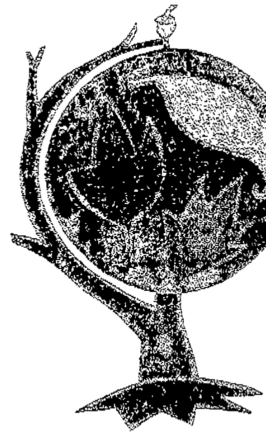
June 2000



Innovation and Sustainable Development

Sustainable development cannot be addressed in isolation from considerations of social and economic well being. Technology enables change but cannot be the sole driver of innovation.

Firms have used technology as an engine of progress since at least the time of the Industrial Revolution, which gave us remarkable ways to marshal the physical world for human benefit. While innovation - the successful implementation of new developments and ideas - depends upon much more than technological advance, technology has consistently provided the opportunities from which we have been able to make and sell better goods and services and to do so more cleanly and more safely.

Many of today's social and economic developments are a result of technical discoveries and developments in fields such as communications, information processing, health sciences and energy supply. These promise smarter, more tailored solutions to the tasks we wish to accomplish. Rather than being monolithic in approach, the tools are used by dynamic and responsive networks of small and large, public and private organizations, working together and in competition in ways that were never before possible.

The changes are tremendous and the opportunities profound. But technology can only be part of achieving a more sustainable development and its contribution is not always as positive as we might wish. Furthermore, other factors that drive and support progress are themselves changing. The well-defined social categories for which post-war Western institutions were designed no longer fit well with people's aspirations and values. Richer countries are experiencing a shift towards an increasingly multidimensional and diverse "Mosaic Society", with uncertain needs but very real concerns about many subjects including science and technology.

At the same time, despite there being greater affluence than at any time in history, most of the world's population remains poor yet very much aware of its relative poverty. For these people, the economic and social benefits of globalization and global markets are increasingly being questioned.

Other writers have offered cogent, visionary ideas of the improved sustainability that can be obtained by marshaling recent developments (see for example Lovins, Natural Capitalism). Our focus in this project has been on how firms can organize themselves to realize these opportunities in ways that benefit and are acceptable to society and also create value.

The approach we suggest is based on understanding how the concepts of corporate social responsibility and eco-efficiency have been implemented and extending these concepts to cover the management of innovation.

Leading companies have built their approaches to sustainable development upon principles such as those in box 1. For existing business operations undergoing normal business development, these are mutually reinforcing principles. They provide a positive and effective framework that firms can use in mitigating environmental impact

Box 1: Corporate responses to eco-efficiency and corporate social responsibility involve:

- Ensuring the corporation understands what society expects of it, in return expressing clearly what the firm itself stands for, then reinforcing these values to stretch the organization and create a spirit of continuous improvement. (Attitude)
- Developing the tools and approaches to improve performance across the social, environmental and economic pillars of sustainable development and incorporating these tools within routine business processes. (Build the capacity to act)
- Setting focused targets and putting in place the means to measure performance and confirm that the targets are being achieved. (Check progress)

and allaying public distrust (see Schmidheiny, Changing Course; Fussler, Eco-Innovation; WBCSD, Corporate Social Responsibility).

The stock market returns achieved by companies included in the recently launched Dow Jones Sustainability Index suggest that investors are recognizing the management qualities that make this possible.

Whereas twenty years ago, most companies based their performance standards on regulatory requirements, today many choose to go beyond regulation because they see commercial benefit in doing so. Established practice in areas such as safety and quality management has demonstrated that uncompromising principles are perfectly compatible with the spirit of continual improvement.

Stakeholder dialog has helped firms learn more about others' points of view and then use this understanding to set better priorities and move away from confrontational approaches. In extending systems of financial control and audit to cover environmental impact, they have recognized the need to gain early "buy in" by ensuring relevance to the specific priorities of individual business units. Technology is playing a central role in moving forward and engineers generally seem to relish the opportunity to find more eco-efficient solutions once the parameters for improvement have been established.

Good Enough or Could Do Better?

This is intended to be a rhetorical question. During the last decade, the arguments and counter-arguments about rates of improvement have been well rehearsed. Economic focus leads to "short-termism". Regulatory frameworks offer too much (or too little) "command and control", so we are not properly pricing public goods, environmental services and social well being. New approaches are uneconomic in the face of established manufacturing capacity.

Undesired impacts are associated with large, interdependent infrastructures (for example, the car, its fuel and the city), so require more systemic approaches that can transcend traditional business and political boundaries and avoid stranded assets. Technical progress is slower than expected, gets sidetracked through lack of customer pressure or creates "rebound effects" by stimulating new demand that consumes the improvements that have been achieved.

These concerns are valid but (with effort and a fair dose of humility) there are ways to overcome them. In some cases, effective solutions are already available; in others, we may need to change the market's rules of the game. For example, it seems likely that economic instruments such as tradable carbon emissions permits will improve the market's effectiveness in dealing with climate change. Demonstrating that these instruments do work well requires agreement on rules and modalities and the willingness to take action and learn from our mistakes.

In other words, sustainable innovation involves risk but it also requires structure. While much can be achieved by "continuing to do better", it will be far more challenging and rewarding to learn to provide mechanisms that will:

- Bring design, smart technologies and the "new economy" together to drive growth in ways that reflects changing concerns and values of a connected world
- Support faster and more sustainable development in the developing nations

We believe that success with these tasks can turn sustainable development into an approach that is intrinsically value creating. But we also believe that some established ways of doing business and the assurance processes that accompany them will need improving in order to achieve this.

For example, sound science is a lynch pin of corporate approaches to technology risk management. Even though no one questions the need for high safety standards, too much recourse to scientific evidence and argument can come across as complacent and paternalistic. The public's sense of the role of technology has changed and its awareness of past mistakes has grown. Today we need to find better ways to show that firms (and governments) are keeping their scientific houses in order.

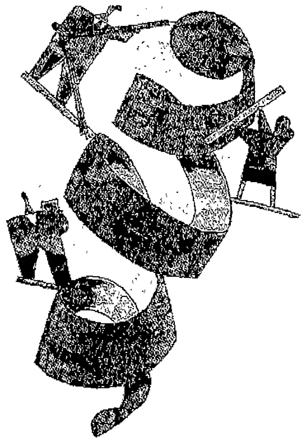
A paradox is that the success of today's activists owes much to their mastery of communication technologies in getting their messages heard. Governments, inter-governmental bodies and corporations now find themselves to be hopelessly cumbersome in the face of resolute single-purpose advocacy. Stakeholder dialog offers a way forward but requires that we learn how to achieve open discussion when the risks seem large and the benefits unclear.

With this background, subsequent chapters describe the work as follows:

- Thinking about innovation and its connection to sustainable development and changing social attitudes and values.
- Lessons to be learned from how corporations committed to sustainable development are already managing these questions.
- International equity, technology cooperation and how companies can use their creative and technical capacities and global outreach to foster more sustainable economic growth within developing nations.
- A management framework for innovation to help companies guide staff through these questions.

The main conclusions in each chapter are used to construct checklists that can be adapted to assess firms' own approaches to sustainable innovation.

Thinking about Innovation and Technology



To achieve greater sustainability, we will need both the experimental spirit of Jazz and the effective governance that GEOPolity can provide. Consumers expect companies to go beyond minimum requirements and be main actors in realizing these conditions.

In preparing for an uncertain future, we need a sense of what might develop while avoiding placing expensive bets on particular outcomes. Scenario planning offers one way to extend our strategic thinking.

The WBCSD used this tool in its Global Scenario and Biotechnology Scenario projects and we found the approach helpful in looking at the broad questions of business-led innovation and use of technology. This section gives a brief summary of these two sets of scenarios. Other publications (see reading list) describe the method and give the complete stories.

The Global Scenarios explored sustainable development in terms of two parameters:

Uncertainty: How we will recognize the resilience, limits and critical thresholds faced within the global ecosystem.

Governance: What forms of social system can best respond to the challenge of sustainable development.

FROG!, *GEOPolity* and *Jazz* describe different ways in which people view and respond to these parameters. The real world reflects aspects of all three.

Some who have worked with the results want to realize the benefits of the dynamic *Jazz* world and look for solutions that will foster its innovative spirit and market-based approach. Others feel that *Jazz* will be a very challenging world in which to live and work and consequently may not deliver everything they wish to achieve. *GEOPolity* offers other ways to approach these challenges.

FROG! - First Raise Our Growth!

FROG! describes a low-trust world in which people focus on jobs, economic survival and short-term financial returns. Although people believe they value sustainable development, local economic pressures dominate their thinking. After all, people (at least those who are already affluent) find it obvious that their neighborhoods have become far cleaner, presumably because they have already adopted the right approaches.

This local focus leads to a poor reading of signals. Signs of global environmental problems - for example the risk of climate change - and growing social inequity either go unnoticed or trigger disagreement about what signs of change mean. No action will be taken until it becomes impossible to continue ignoring the signs, by which time it will be correspondingly harder to respond effectively.

In the meantime, the public takes advantage of what business offers and punishes companies that are seen to cause harm through their goods and services and ways of operating. Voter-sensitive governments ensure that exposures are discovered and dealt with promptly, so firms act defensively to anticipate and limit liabilities.

FROG! generates solid economic growth yet this will probably be unsustainable because no one takes care to address sustainability as their ambition. There will be continued technological progress but this is unlikely to be directed towards greater sustainability. Existing approaches, ways of working, etc., will be extended rather than replaced by something better. There will be an emphasis on tools for monitoring, quantifying and documenting the performance of existing operations rather than going pro-actively beyond these standards.

Governments will legislate, set technology policies and support R&D in order to stimulate local competitiveness and aspirations. Aspects of these policies, and the innovations that result, may accidentally align with the ambitions of sustainable development. Ambivalent consumer attitudes and lack of long-term thinking about ethical and other implications will limit the sustainable value of the results.

GEOPolity

GEOPolity starts with a recognized environmental crisis. The palpable failure of national governments and multinational companies to deal with the crisis as well as past problems destroys the already limited credibility of these existing institutions. People recognize the need for new mechanisms to address global issues such as the health of the planet and to resolve conflicts of interest in a peaceful manner.

The spirit of the age – the "mood of the millennium" - captures the attention of people who have the ambition to put things right. This aligns their effort into a collective sense of purpose and they build an interlocking global governance system coordinated at an international level.

GEOPolity reflects a human desire for big solutions to grand challenges. Its institutions work towards market-based solutions but set new rules and regulatory frameworks for markets to follow. To achieve greater sustainability, these global institutions may engage companies in a joint attack on big challenges.

Consequently, this scenario will develop world-scale technologies and drive forward major global infrastructure projects. One can imagine the 21st century equivalents of *Concorde* and *Apollo*, designed to address climate change, provide equitable supplies of clean water and food, manage critical eco-systems and foster "connectedness" and opportunity.

In such a world, technological prowess will be a key tool that firms use to ensure credibility and secure their license to operate, shape legislation and achieve competitive advantage. Technology-rich companies may see great value in encouraging and becoming contractors to these initiatives. (Today's nuclear industry developed very rapidly in a world rather reminiscent of *GEOPolity*.) As symbols of their prowess, they are likely to prefer process and product technologies that can be patented to intangible knowledge-based approaches.

A strength of *GEOPolity* is its ability to set decent rules and regulations to steer the collective effort. This scenario will probably be very effective if global standards and regulatory frameworks are needed (and can be agreed) in order to build better solutions.

Its weaknesses include the difficulty of changing existing institutions that already feel empowered to deal with matters and the general risk of bureaucracy and slow response associated with "big institution" processes.

As a result, there may be undue up-front selection of "winners" within *GEOPolity*, too little engagement of customers in the choices being offered and too little attention to unintended consequences and side effects.

Jazz

Jazz describes a world in which people recognize that they can care about issues such as sustainable development without needing others to legislate the solution. These people harness the markets to find solutions to their concerns, in the process creating a complex market-led world of *ad hoc* experimentation.

This is a demanding world of partnerships between consumers, businesses, governments and non-governmental organizations. Alliances form and break fluidly to meet civil demands. High transparency enforces quick learning by allowing the public to identify and punish companies and governments that break the social norms. In *Jazz*, the public sees no need to applaud expert opinion for its own sake.

In this world, technology is a cross-fertilizer that enables firms to work within diverse partnerships but it also creates challenges for them to overcome. For example, in a transparent world, innovative companies need new ways to safeguard their intellectual assets. This will encourage greater speed of use of these ideas and emphasize the less-tangible, knowledge-rich technologies suitable within a service economy.

Jazz can align people worldwide to common cause but the nature of their alignment cannot be taken for granted. Initiatives such as the redesign of large infrastructures or the handling of sensitive new technologies still require a consensual basis and public ground swell to move forward. Furthermore, even though its public wants to achieve progress across a broad front, communities and organizations that lack resources and skills may find it hard to join the *Jazz* band.

Implications for Company-led Innovation

Scenarios help focus our aspirations and actions by sharpening our understanding of the diverse forces within today's society. Of the three Global Scenarios, *GEOPolity* and *Jazz* appear more able to support sustainable development. Signs of all three can be seen around us today.

Many people consider *Jazz* to be the more appealing world to aim for, because of its sense of personal responsibility, collective effort and transparency but it also seems important to maintain the framework-setting strengths of *GEOPolity*.

The stories suggest (see Dearing, Have We the Foresight for Sustainable Development) that sustainable innovation will involve companies in:

- Taking advantage of dynamic, experimental approaches and providing consumers the information and price signals to exercise informed choice.
- Being willing to build and work within institutional structures to coordinate large-scale tasks and constrain unacceptable behavior while avoiding the tendency to "plan mega-solutions" as a matter of course.
- Expanding local focus to legitimize action on a broader front, for example by actively disclosing impact and working with the public on risks and benefits.

An important conclusion is that the approaches taken to education, regulation, social values, public understanding of complex subjects such as technological risk and the precautionary principle strongly influence how well societies can address their sustainable development. With no single point of leverage, a broad base of action is needed that will extend throughout and beyond the firm.

The Biotechnology Scenarios

This project was carried out after the Global project was complete. It focused on the certainty that someone, somewhere will put scientific developments in areas such as biotechnology to use and the inevitable human anxieties about the unknown.

It generated three scenarios, *The Domino Effect*, *The Hare and the Tortoise* and *Biotrust*. The scenarios explore the impact of unintended consequences on the acceptability of a technology, the balance of risk and liability issues and consumer choice on sustainable development and the consequences of a widely accepted biotechnology industry.

These scenarios build on similar forces as the Global project and also draw similar conclusions about the importance of linking public initiative with framework setting approaches.

Depending on the nature of public reaction to the unintended events that new technology triggers, the acceptance of technology can vary widely. This is the story that is explored in *The Domino Effect*. This presents a low-trust world in which events take a negative course, leading to heavy regulation: in the language of the Global scenarios, *FROG!* leading to *GEOPolity*.

Apart from any such event, an industry that grows up around the new technology could prosper or not for reasons that depend on factors other than technology or sustainable development. This story is explored in *The Hare and the Tortoise*, a *Jazz*-like world in which new technology is not much of a player.

The third unknown has to do with the consequences of a successful and widely accepted technology-based industry. What kind of world might this produce and how might acceptance come about and be assured? This is the story of *Biotrust*, also a *Jazz*-like world but with some of the framework overtones of *GEOPolity*. Of the three scenarios, this is the one that achieves the most extensive application of the new development.

These stories help focus attention onto the sources of the unpredictable and so help us appreciate what imaginative worlds it would be wise to inhabit (at least for a while) if we are interested in the future of technology and want to learn how to achieve the desired outcome.

Social Expectations as a Driver for Sustainable Innovation

We discussed these conclusions with people and organizations worldwide concerned with sustainable development to learn their views on the role of company-led innovation. What we heard confirmed many of the tensions apparent in the Global and Biotechnology Scenario studies:

- growing awareness of social values and environmental issues,
- rediscovery of the sense of co-dependency,
- a more determined public with different priorities for innovation and use of technology.

The results of part of this study, the 1999 Regional Dialogs, are given in the Appendix.

"People are placing less value on technological progress and economic growth and relatively more value on conserving and protecting the quality of the environment in which they live."

This quote came from a book written over twenty years ago (see Schein, Career Dynamics) but the 1999 dialogs reinforced its message that innovation is widely desired but not always seen to be positive.

Many people perceive innovation as technological progress creating indiscriminate economic growth and leading to depletion of the natural environment and increasing pollution.

A real commitment on the part of corporations, rather than technology itself, is seen as the pre-requisite for creating the conditions for sustainable growth and better quality of life. Consumers expect companies to go beyond minimum requirements and be main actors in realizing these conditions.

Leading companies have recognized that resolving these tensions provides the only basis for their profitability in the years ahead. Put one way (by Richard Branson) *"the brands that will be big in the future will be those that tap into the social changes that are taking place"*. Or as Roger Cowe expressed it recently ("Account-Ability", The Planet on Sunday):

"Once a company has acknowledged it has to account for pollution ... it is harder to deny wider social responsibilities. And once outsiders have been through the gates, it is impossible to stop them looking beyond one narrow aspect of business.

Checklist 1: Playing within the Well-tempered *Jazz* Band

- Are our actions in tune with *Jazz*, more like the formal structures of baroque cantatas or simply discordant? Do we really want to be challenged to experiment and innovate, or are we accepting the security of established management processes and regulatory frameworks?
- Do we know what tune people would like us to play? Will they find our tune too hard to share? Can we play theirs?
- Are we willing to form partnerships and alliances that can create these new harmonies or do we join with the rest of the woodwinds (for example, our industry association) and argue that it is the percussion's turn to play? Have we also got the imagination and energy to build and work within the frameworks that can move us forward?

Curiously, this odd little world of social auditing threatens to fuel a debate about the purpose and nature of 21st century capitalism which has escaped the politicians for decades."

The sense is that markets will increasingly be characterized by the power of vision: to think the future, imagine the future and shape the future. In other words, firms are being expected, and some are themselves expecting, to address sustainability by design. Examples such as Dupont's "To Do list for the Planet" demonstrate that this is already happening.